US010606563B2

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Wolfram et al.

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(54) **PROGRAMMING IN A PRECISE SYNTAX USING NATURAL LANGUAGE**

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(73) Assignee: **Wolfram Alpha LLC**, Champaign, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Mar. 29, 2019**

(65) **Prior Publication Data**

US 2019/0227773 A1 Jul. 25, 2019

Related U.S. Application Data

(63) Continuation of application No. 15/852,947, filed on Dec. 22, 2017, now Pat. No. 10,248,388, which is a continuation of application No. 13/678,168, filed on Nov. 15, 2012, now Pat. No. 9,851,950.

(60) Provisional application No. 61/560,163, filed on Nov. 15, 2011.

(51) **Int. Cl.**
G06F 17/28 (2006.01)
G06F 8/30 (2018.01)

(52) **U.S. Cl.**
CPC ***G06F 8/30*** (2013.01); ***G06F 17/28*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 8/00–78; G06F 17/20–289
See application file for complete search history.

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(57) **ABSTRACT**

A method facilitates development of instructions in a precise syntax, such as built-in functions of a computational system such as a spreadsheet application, using natural language (NL) input. A user may enter NL input in a workspace. An NL processing system may process the NL input to generate instruction(s) in a precise syntax that corresponds to the NL input. The instruction(s) in the precise syntax then may be included in the workspace.

15 Claims, 13 Drawing Sheets

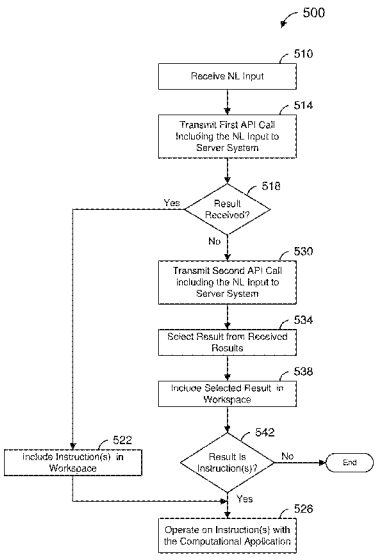

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FIG. 1

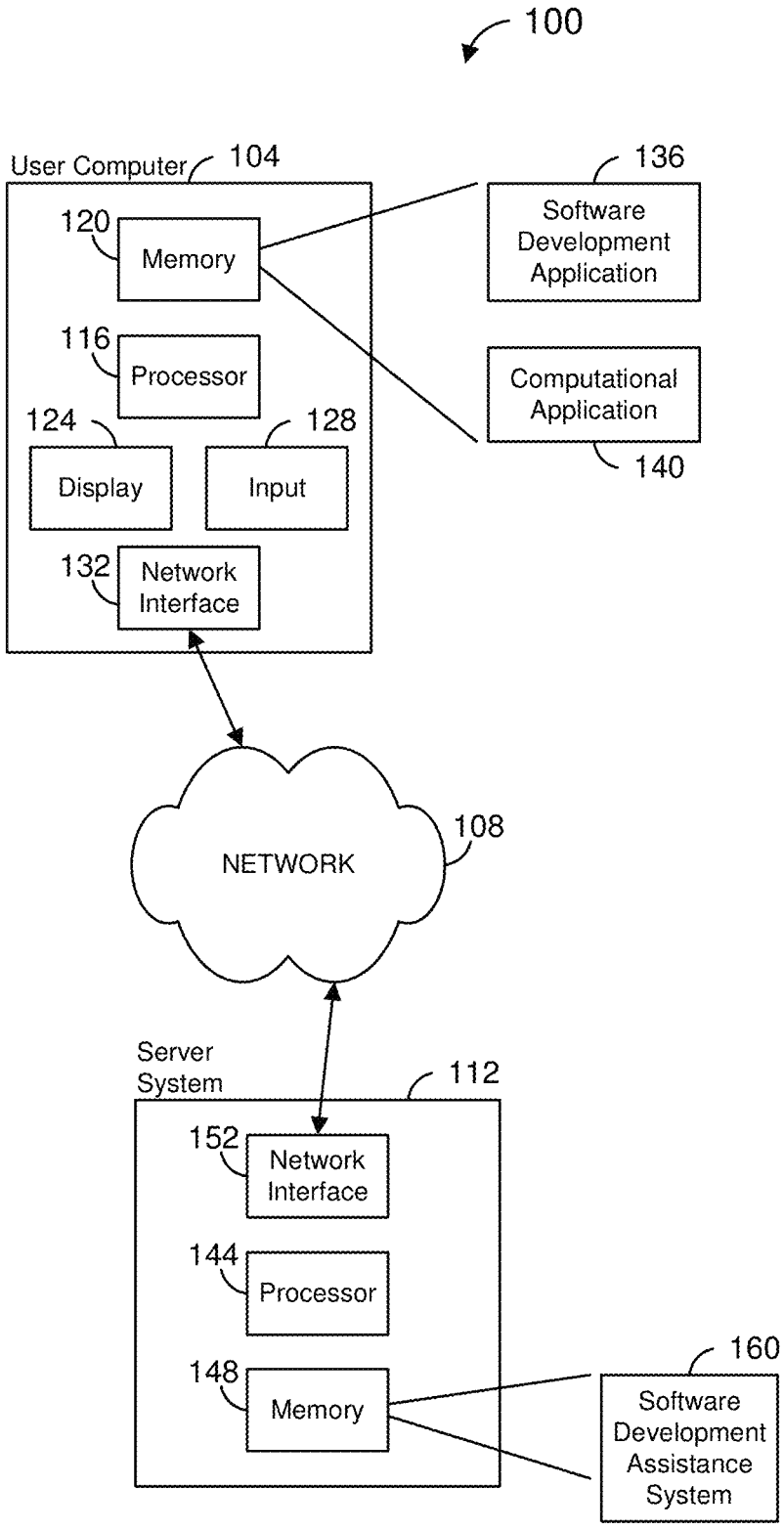

100
User Computer
104
120
Memory
116
Processor
124
Display
128
Input
132
Network Interface
136
Software Development Application
Computational Application
140
NETWORK
108
Server System
112
152
Network Interface
144
Processor
148
Memory
160
Software Development Assistance System

FIG. 2

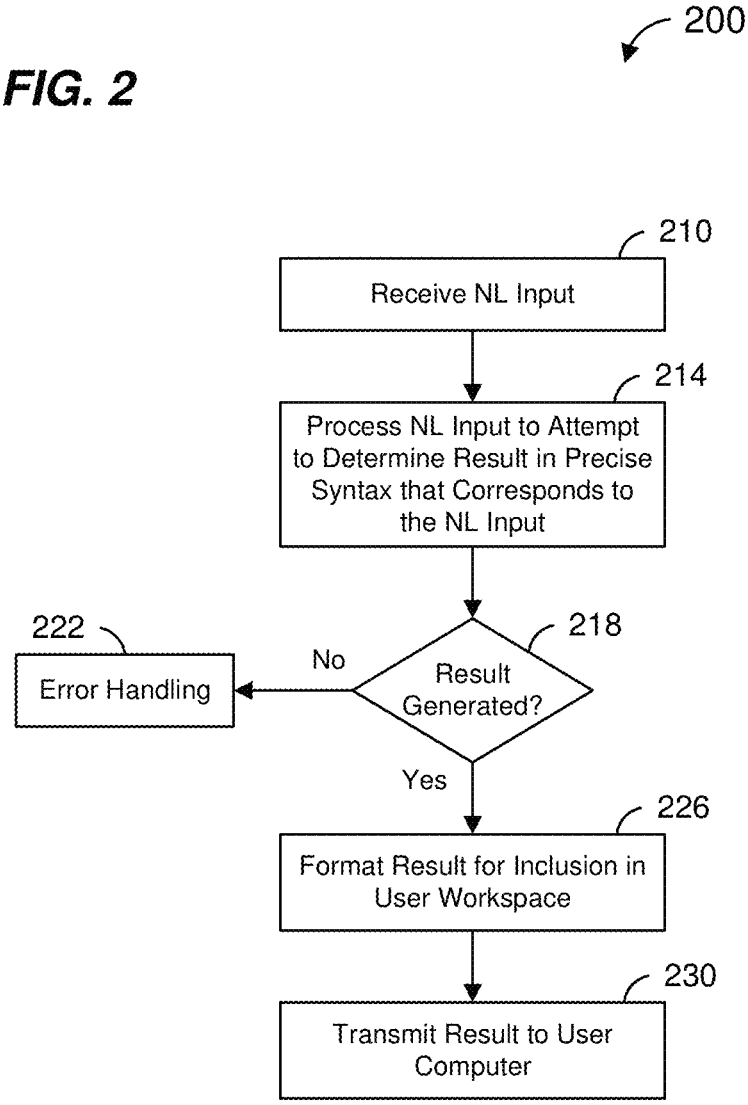

200
210
Receive NL Input
214
Process NL Input to Attempt to Determine Result in Precise Syntax that Corresponds to the NL Input
218
Result Generated?
No
222
Error Handling
Yes
226
Format Result for Inclusion in User Workspace
230
Transmit Result to User Computer

FIG. 3

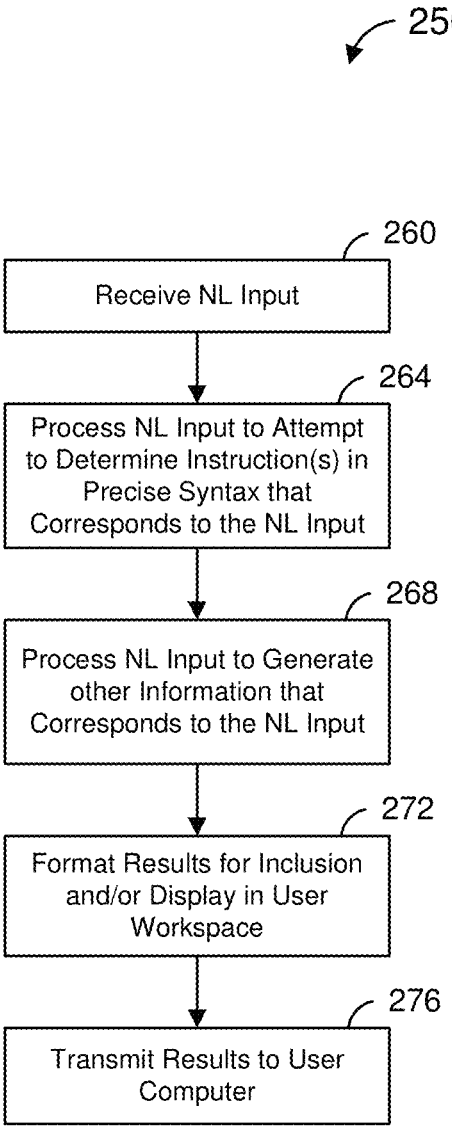

250
260
Receive NL Input
264
Process NL Input to Attempt to Determine Instruction(s) in Precise Syntax that Corresponds to the NL Input
268
Process NL Input to Generate other Information that Corresponds to the NL Input
272
Format Results for Inclusion and/or Display in User Workspace
276
Transmit Results to User Computer

FIG. 4

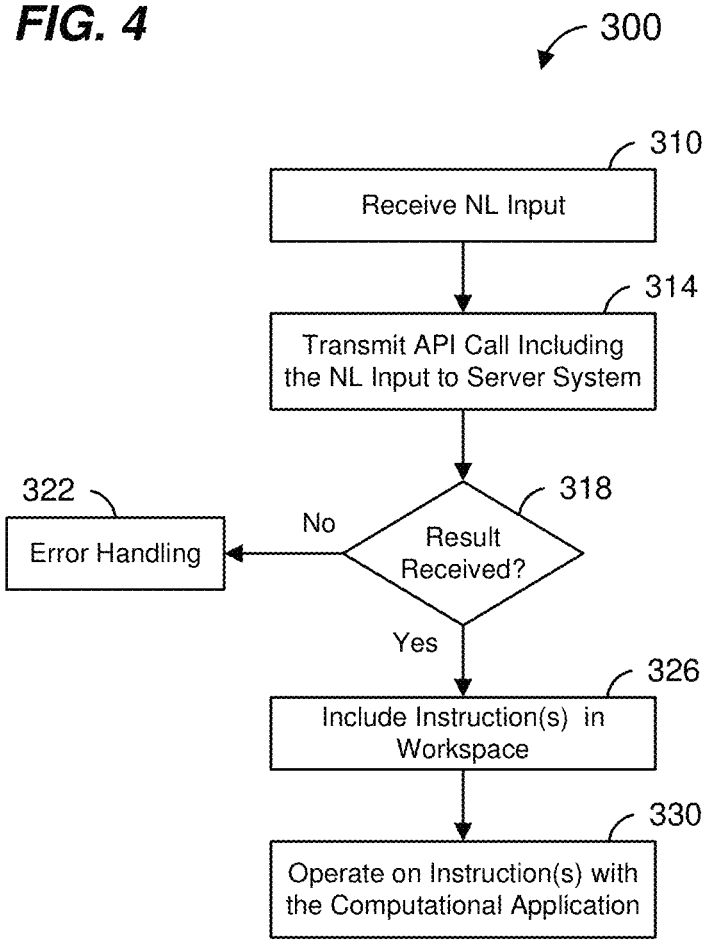

300
310
Receive NL Input
314
Transmit API Call Including the NL Input to Server System
318
Result Received?
No
322
Error Handling
Yes
326
Include Instruction(s) in Workspace
330
Operate on Instruction(s) with the Computational Application

FIG. 5A

FIG. 5B

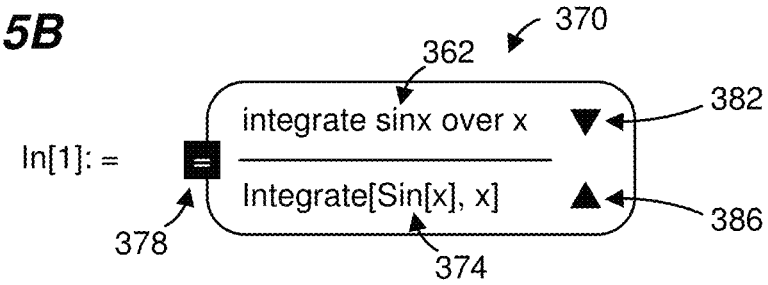


FIG. 5C

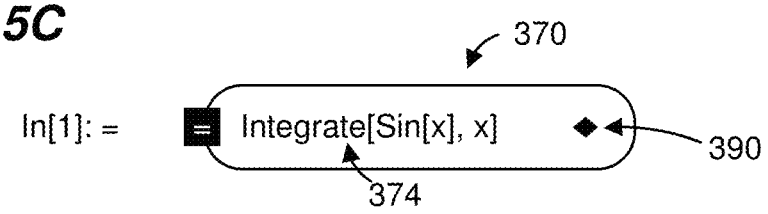


FIG. 5D

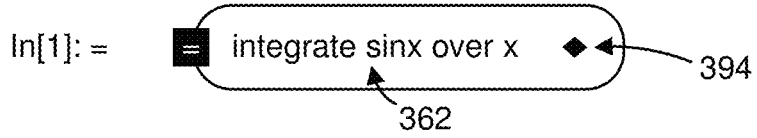


FIG. 5E

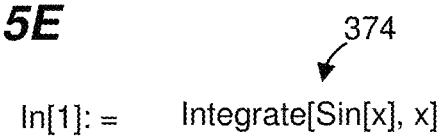


FIG. 6

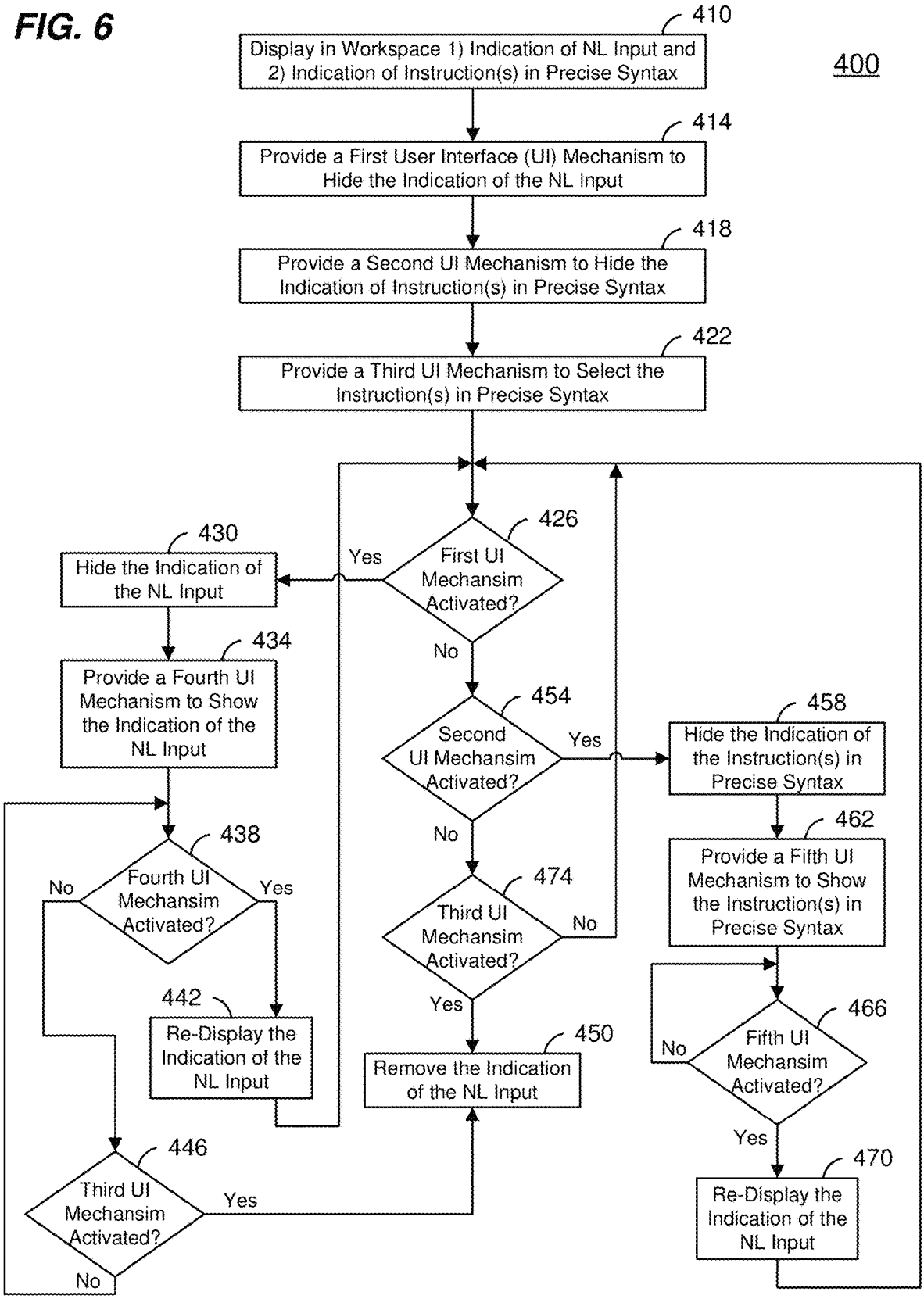

400
410
Display in Workspace 1) Indication of NL Input and 2) Indication of Instruction(s) in Precise Syntax
414
Provide a First User Interface (UI) Mechanism to Hide the Indication of the NL Input
418
Provide a Second UI Mechanism to Hide the Indication of Instruction(s) in Precise Syntax
422
Provide a Third UI Mechanism to Select the Instruction(s) in Precise Syntax
426
First UI Mechansim Activated?
Yes
No
430
Hide the Indication of the NL Input
434
Provide a Fourth UI Mechanism to Show the Indication of the NL Input
438
Fourth UI Mechansim Activated?
No
Yes
442
Re-Display the Indication of the NL Input
446
Third UI Mechansim Activated?
Yes
No
454
Second UI Mechansim Activated?
Yes
No
458
Hide the Indication of the Instruction(s) in Precise Syntax
462
Provide a Fifth UI Mechanism to Show the Instruction(s) in Precise Syntax
466
Fifth UI Mechansim Activated?
No
Yes
470
Re-Display the Indication of the NL Input
474
Third UI Mechansim Activated?
No
Yes
450
Remove the Indication of the NL Input

FIG. 7

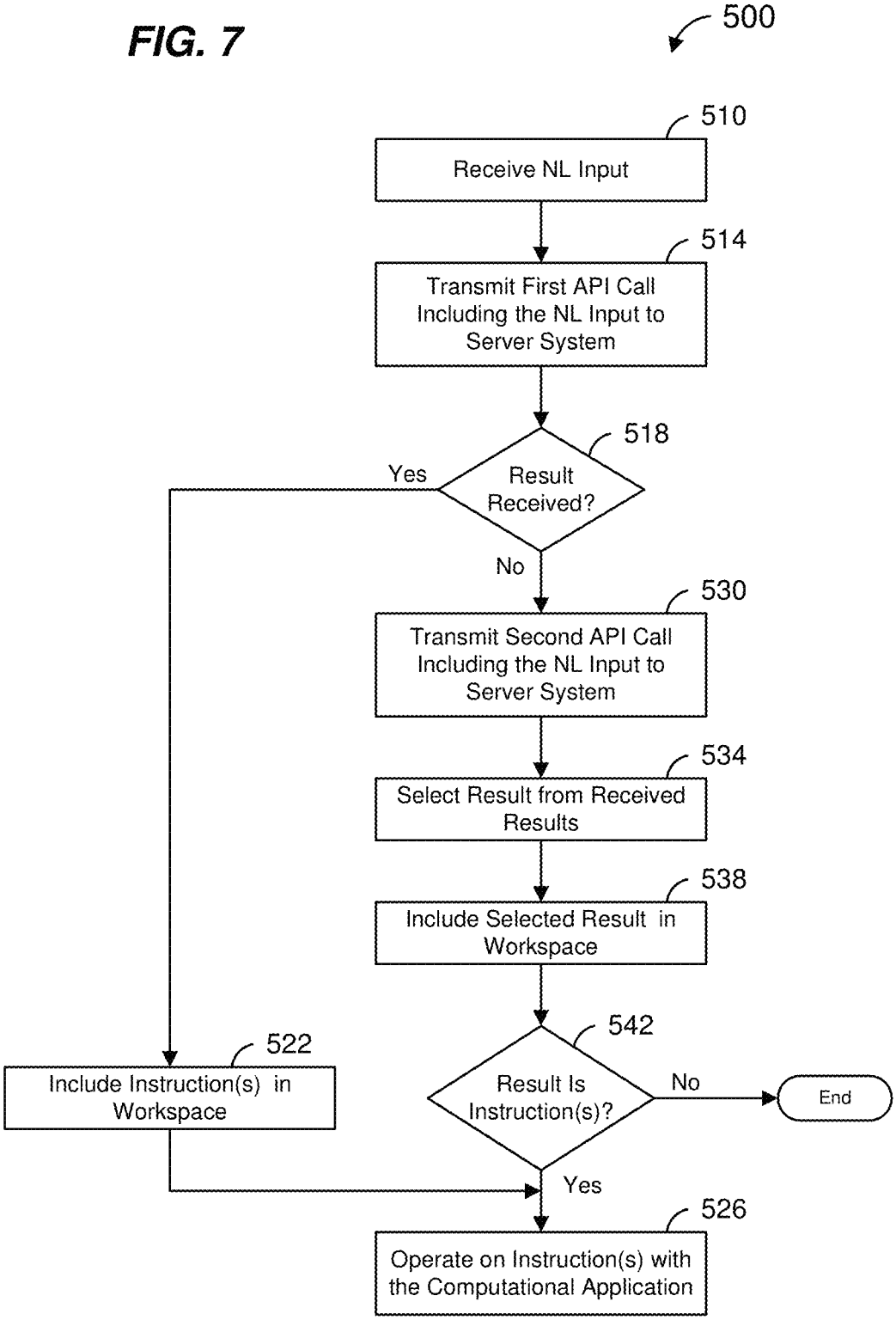

500
510
Receive NL Input
514
Transmit First API Call Including the NL Input to Server System
518
Result Received?
Yes
No
530
Transmit Second API Call Including the NL Input to Server System
534
Select Result from Received Results
538
Include Selected Result in Workspace
542
Result Is Instruction(s)?
No
End
Yes
522
Include Instruction(s) in Workspace
526
Operate on Instruction(s) with the Computational Application

FIG. 8A

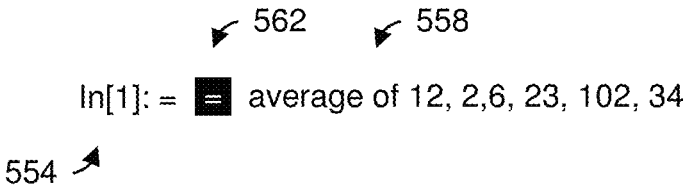

562
558
In[1]: =
average of 12, 2,6, 23, 102, 34
554

FIG. 8B

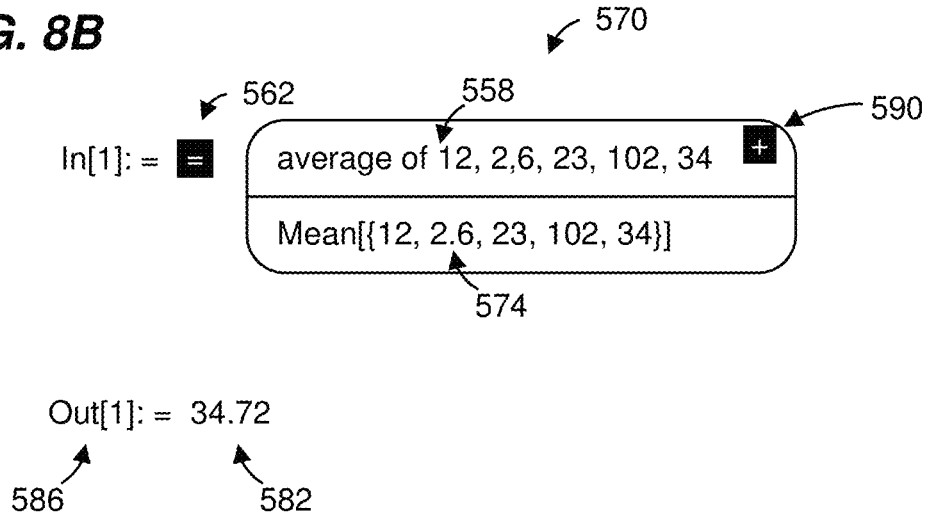

570
562
558
590
In[1]: =
average of 12, 2,6, 23, 102, 34
Mean[{12, 2.6, 23, 102, 34}]
574
Out[1]: = 34.72
586
582

FIG. 9A

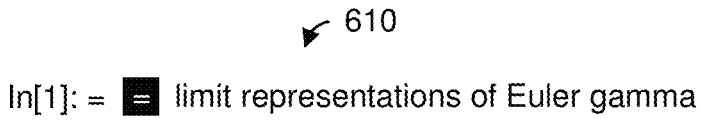

610
In[1]: =
limit representations of Euler gamma

FIG. 9B

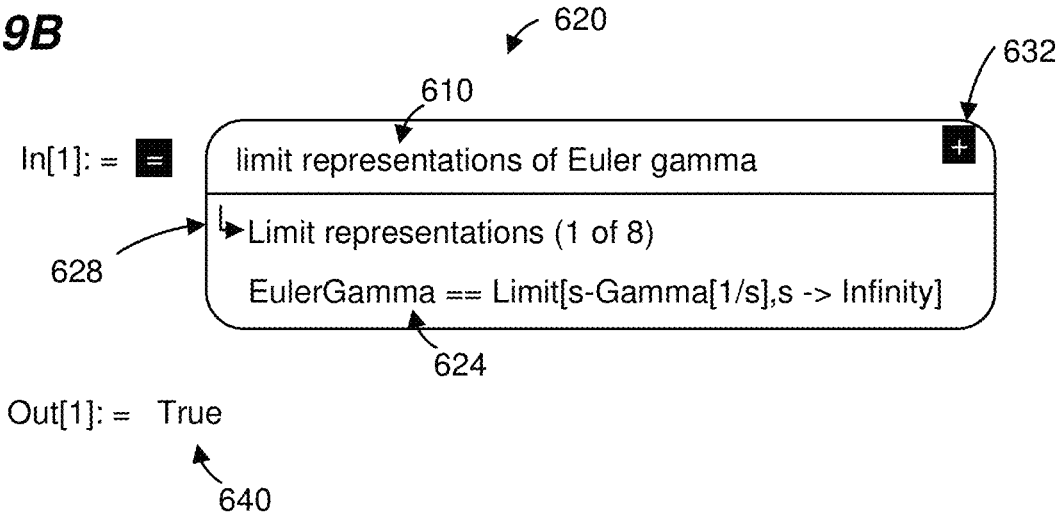
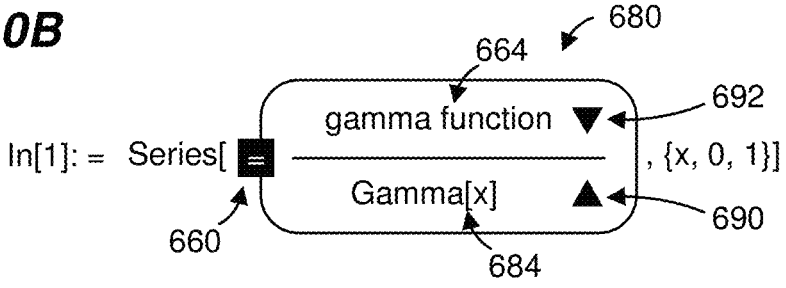

620
632
610
In[1]: =
limit representations of Euler gamma
Limit representations (1 of 8)
628
EulerGamma == Limit[s-Gamma[1/s],s -> Infinity]
624
Out[1]: = True
640

FIG. 10A

FIG. 10B



$$\text{Out[1]: } \frac{1}{x} - \text{EulerGamma} + \frac{1}{12}\left(6\,\text{EulerGamma}^2 + \pi^2\right)x + o[x]^2$$

686

FIG. 10C

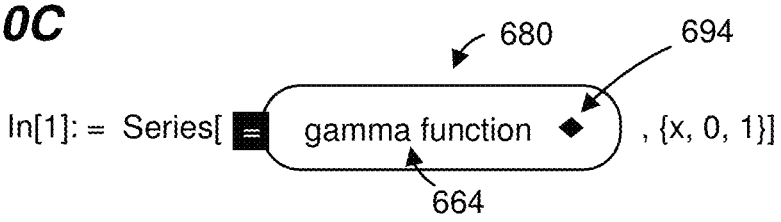


FIG. 10D

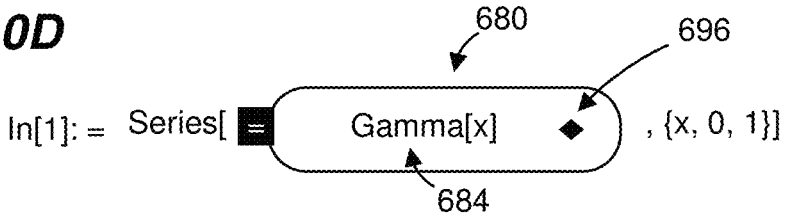


FIG. 10E

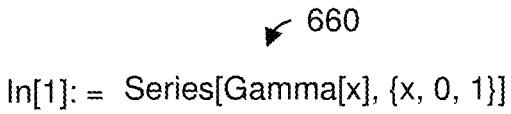


FIG. 11

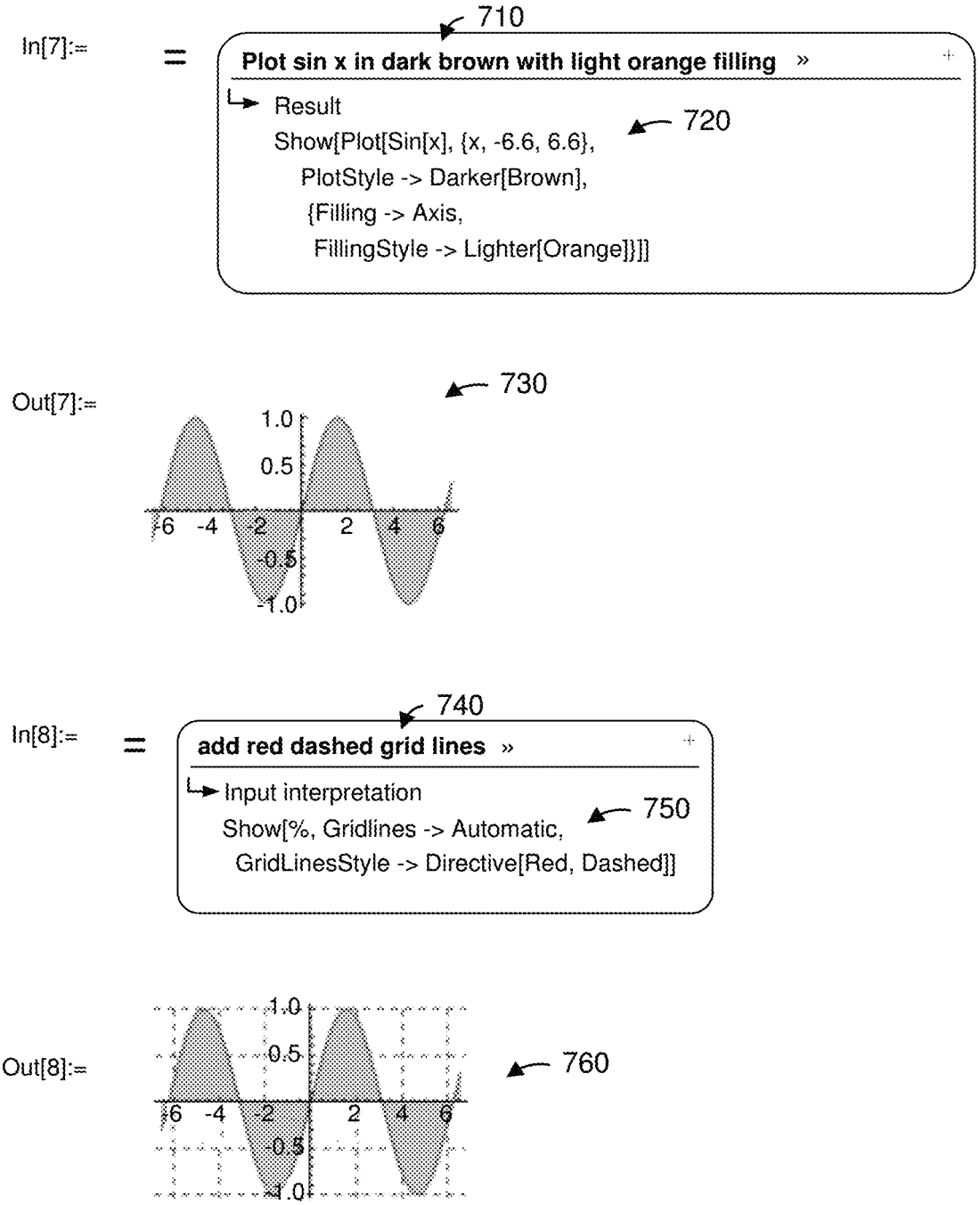

In[7]:=
710
Plot sin x in dark brown with light orange filling »
Result
Show[Plot[Sin[x], {x, -6.6, 6.6},
720
PlotStyle -> Darker[Brown],
{Filling -> Axis,
FillingStyle -> Lighter[Orange]}]]
Out[7]:=
730
1.0
0.5
-6 -4 -2 2 4 6
-0.5
-1.0
In[8]:=
740
add red dashed grid lines »
Input interpretation
Show[%, Gridlines -> Automatic,
750
GridLinesStyle -> Directive[Red, Dashed]]
Out[8]:=
760
1.0
0.5
-6 -4 -2 2 4 6
-0.5
-1.0

FIG. 12A

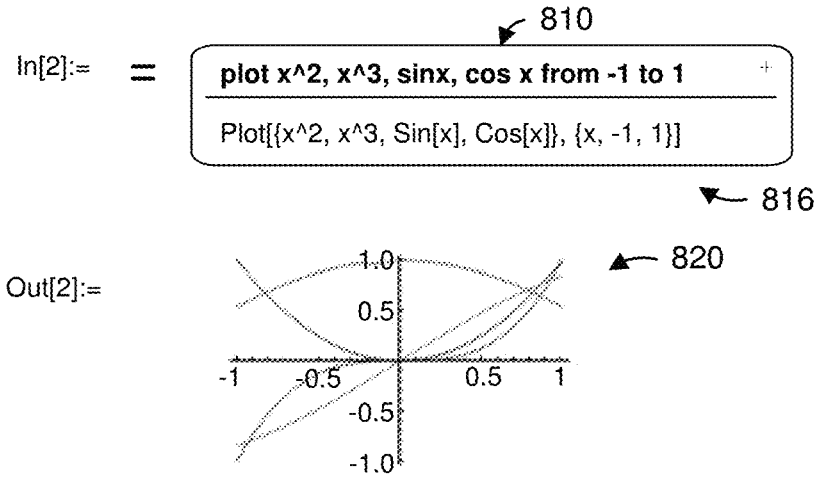


FIG. 12B

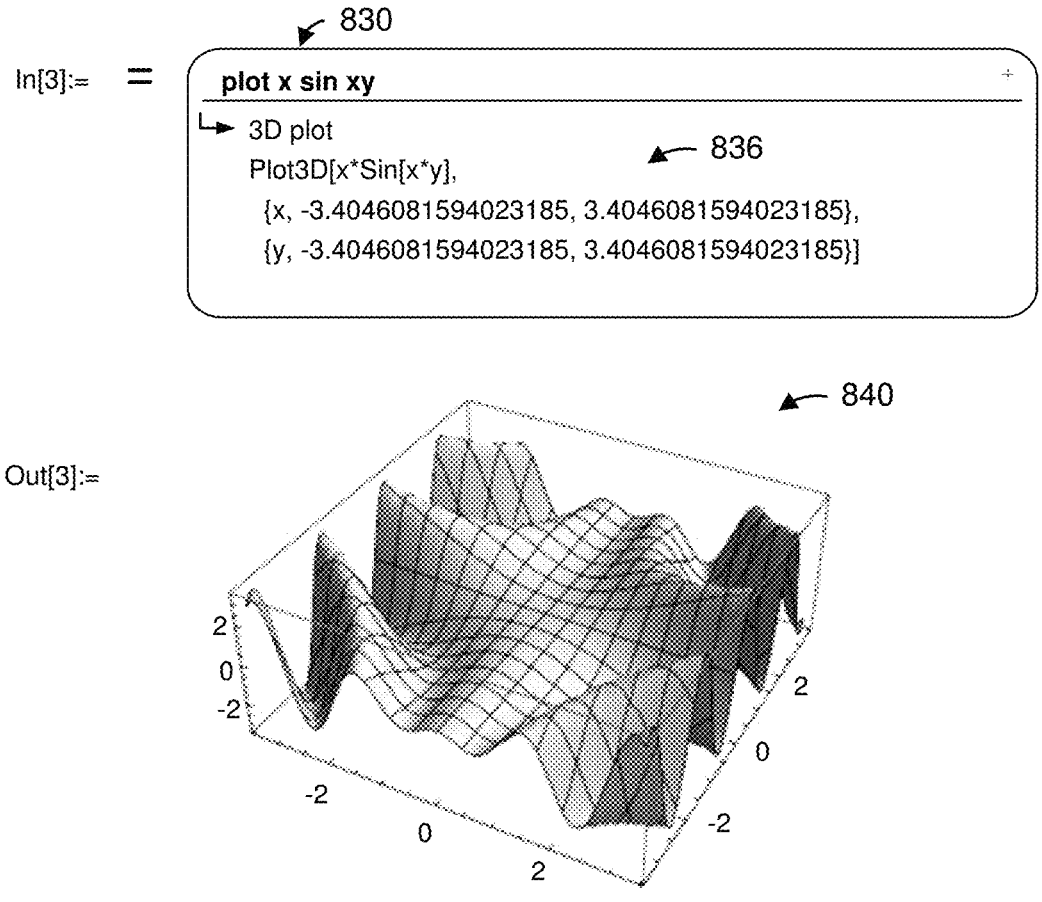
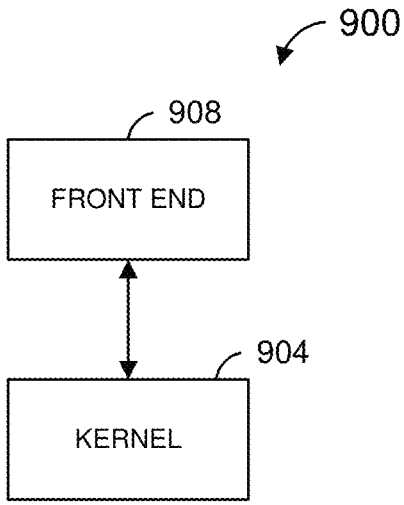


FIG. 13



PROGRAMMING IN A PRECISE SYNTAX USING NATURAL LANGUAGE

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation of U.S. patent application Ser. No. 15/852,947 (now U.S. Pat. No. 10,248,388), entitled "Programming in a Precise Syntax Using Natural Language," filed on Dec. 22, 2017, which is a continuation of U.S. patent application Ser. No. 13/678,168 (now U.S. Pat. No. 9,851,950), entitled "Programming in a Precise Syntax Using Natural Language," filed on Nov. 15, 2012, which claims the benefit of U.S. Provisional Application No. 61/560,163, entitled "Programming in a Precise Syntax Using Natural Language," filed on Nov. 15, 2011. All of the applications referenced above are hereby incorporated by reference herein in their entireties.

FIELD OF THE DISCLOSURE

The present disclosure generally relates to systems that enable generation of instructions in a precise syntax, such as software source code or built-in functions of a computational system, using natural language input.

BACKGROUND

Software programming source code must be written in a precise syntax so that the compiler or interpreter can correctly convert the source code to machine code. When there are errors in the syntax of the source code, the compiler/interpreter cannot convert the source code to machine code, or converts the source code in a manner that was not intended by the author of the source code. For a novice, learning the correct syntax of a software programming language is burdensome and time consuming. Even for an experienced programmer, learning the correct syntax for a function of which the programmer is not yet familiar is time consuming. For example, the programmer may need to consult a reference (e.g., a textbook) to find a suitable function and then learn the correct syntax for using the function.

Some programming systems provide a graphical user interface to permit a user to create a program. For example, a user can create a program by spatially arranging and connecting boxes with arrows, and associating textual expressions with the boxes. The textual expressions are in a precise context and define the actions to be taken upon input to a box.

This disclosure will refer to example implementations in the context of the MATHEMATICA® computational system available from Wolfram Research, Inc. The methods and system described herein are more general and could be implemented in a variety of environments such as in other computational systems and in software development systems (e.g., source code development systems).

MATHEMATICA® is a powerful computational tool that can evaluate general symbolic expressions, as well as mathematical and numeric expressions. A unifying feature of MATHEMATICA® is that everything is internally represented as a symbolic expression, with all more specific data types treated as special cases—symbols to which additional rules apply. MATHEMATICA® is an interpreted language, with a notion of "evaluation" of symbolic expressions. Evaluation consists in applying to any symbolic expression all transformation rules that fit that expression.

In the MATHEMATICA® software system, a user can create interactive electronic documents referred to as "notebooks." Various expressions, including numeric and symbolic expressions, can be entered into a notebook via a keyboard, for example, and a user can cause the expression to be evaluated. As a simple example, a user could set a variable x to the numeric value 5 by typing "x=5" into the notebook and then pressing "ENTER" while holding down the "SHIFT" key. This is shorthand for the expression Set[x, 5], calling the built in function "Set".

In response, the MATHEMATICA® software system conceptually sets the abstract variable x to the value 5. The symbolic expression "x" can, when evaluated, be replaced by the symbol 5. This is one technique by which an interpreted symbolic language may implement variables and variable assignments.

Next, the user could type in an expression x2 by typing "x^2" into the notebook. To evaluate this expression, the user could then press "Enter" while holding down the "Shift" key. In response, the MATHEMATICA® software system evaluates x2 based on the current value of x (set by the user to 5) and would then display "25" in the notebook. To have the notebook display the value of x2 for a different value of x, the user could first type into the notebook the new value of x. For example, the user could type "x=7" into the notebook and then pressing "Shift" and "Enter". In response, the MATHEMATICA® software system resets the variable x to the value 7. Next, the user could retype "x^2" into the notebook and then press "Shift" and "Enter". Alternatively, instead of retyping "x^2" into the notebook, the user could place a cursor on or next to the previously entered expression "x^2" and then press "Shift" and "Enter". In response, the MATHEMATICA® software system evaluates x2 based on the new value of x (set by the user to 7) and would then display "49" in the notebook.

If no value has been assigned to a symbol, evaluation will return the symbol itself unchanged. Thus if a user types x^2, holds "shift" and "enter", without any previous "Set" operation, the MATHEMATICA® software system will return x2. The system knows various rules to apply to compound symbolic expressions (through functions like "Expand" or "Simplify", for example), whether their component subexpressions have "Set" values or not.

Spreadsheet software applications, such as the EXCEL® software application available from Microsoft Corporation, permit a user to create spreadsheets comprising grids of cells. In a spreadsheet, a value in one cell may be dependent upon a value in one or more other cells. For example, a user may assign a formula to a first cell that uses a value from a second cell. Then, the spreadsheet application will calculate an output of the formula using the value from the second cell, and will display the calculated value in the first cell. Such applications require inputs to the first cell in a numeric form, need an explicit formula taking numeric input to relate the contents of the second cell to the numeric values in the first, and output numeric output to the second cell.

SUMMARY OF THE DISCLOSURE

Methods and systems disclosed herein facilitate development of instructions in a precise syntax, such as software source code or built-in functions of a computational system (e.g., a spreadsheet application), using natural language (NL) input. A user may enter NL input in a workspace. An NL processing system may process the NL input to generate

instruction(s) in a precise syntax that corresponds to the NL input. The instruction(s) in the precise syntax then may be included in the workspace.

In an embodiment, a method includes: receiving, via a user interface device, user input for inclusion in a workspace document, wherein the workspace document is displayed in a graphical user interface of a software development application that, when executed by one or more computer processors, is configured to evaluate instructions in a precise syntax; after receiving the user input, displaying, on a display device, the user input in the workspace document; determining, at the one or more computer processors, whether at least a portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax; and when it is determined that at least the portion of the user input is in the precise syntax, evaluating, at the one or more computer processors, at least the portion of the user input according to the precise syntax. The method also includes, when it is determined that at least the portion of the user input is in the imprecise syntax: generating, at the one or more computer processors, an application programming interface (API) call that includes i) the at least the portion of the user input in the imprecise syntax, and ii) information indicating a result of a previous evaluation, by the software development application, of a user input previously entered into the workspace document, sending, by the one or more computer processors, the API call to a natural language processing (NLP) system implemented by one or more computer processors, processing, at the NLP system, the API call to determine the instruction in the precise syntax that corresponds to the user input in the imprecise syntax, wherein the instruction in the precise syntax is for generating a modification of the result of the previous evaluation, formatting, at the NLP system, the instruction in the precise syntax according to a format recognized by the software development application, receiving, at the one or more computer processors, the instruction in the precise syntax from the NLP system, wherein receiving the instruction in the precise syntax from the NLP system is responsive to sending the API call to the NLP system, including, by one or more computer processors, the instruction in the precise syntax in the workspace document such that the software development application executed by one or more computer processors can evaluate the instruction in the precise syntax, and after including the instruction in the precise syntax in the workspace document, evaluating, at one or more computing devices, the instruction in the precise syntax.

In another embodiment, one or more tangible, non-transitory computer readable storage media storing machine readable instructions that, when executed by one or more computer processors, cause the one or more processors to: receive, via a user interface device, user input for inclusion in a workspace document, wherein the workspace document is displayed in a graphical user interface of a software development application that, when executed by one or more computer processors, is configured to evaluate instructions in a precise syntax; after receiving the user input, display, on a display device, the user input in the workspace document; determine whether at least a portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax; and when it is determined that at least the portion of the user input is in the precise syntax, evaluate at least the portion of the user input according to the precise syntax. The one or more tangible, non-transitory computer readable storage media also store machine readable instructions that, when executed by one or more computer processors, cause the one or more processors to: when it is determined that at least the portion of the user input is in the imprecise syntax, generate an application programming interface (API) call that includes i) the at least the portion of the user input in the imprecise syntax, and ii) information indicating a result of a previous evaluation, by the software development application, of a user input previously entered into the workspace document, send the API call to a natural language processing (NLP) system implemented by the one or more computer processors, process, at the NLP system, the API call to determine the instruction in the precise syntax that corresponds to the user input in the imprecise syntax, wherein the instruction in the precise syntax is for generating a modification of the result of the previous evaluation, format, at the NLP system, the instruction in the precise syntax according to a format recognized by the spreadsheet application, receive the instruction in the precise syntax from the NLP system, wherein receiving the instruction in the precise syntax from the NLP system is responsive to sending the API call to the NLP system, include the instruction in the precise syntax in the workspace document such that the spreadsheet application executed by one or more computer processors can evaluate the instruction in the precise syntax, and after including the instruction in the precise syntax in the workspace document, evaluate the instruction in the precise syntax.

In yet another embodiment, a system, comprises: one or more computer processors; and one or more tangible, non-transitory computer readable storage media that store machine readable instructions that, when executed by one or more computer processors, cause the one or more processors to: receive, via a user interface device, user input for inclusion in a workspace document, wherein the workspace document is displayed in a graphical user interface of a software development application that, when executed by one or more computer processors, is configured to evaluate instructions in a precise syntax; after receiving the user input, display, on a display device, the user input in the workspace document; determine whether at least a portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax; and when it is determined that at least the portion of the user input is in the precise syntax, evaluate at least the portion of the user input according to the precise syntax. The one or more tangible, non-transitory computer readable storage media also store machine readable instructions that, when executed by one or more computer processors, cause the one or more processors to: when it is determined that at least the portion of the user input is in the imprecise syntax, generate an application programming interface (API) call that includes i) the at least the portion of the user input in the imprecise syntax, and ii) information indicating a result of a previous evaluation, by the software development application, of a user input previously entered into the workspace document, send the API call to a natural language processing (NLP) system implemented by the one or more computer processors, process, at the NLP system, the API call to determine the instruction in the precise syntax that corresponds to the user input in the imprecise syntax, wherein the instruction in the precise syntax is for generating a modification of the result of the previous evaluation, format, at the NLP system, the instruction in the precise syntax according to a format recognized by the spreadsheet application, receive the instruction in the precise syntax from the NLP system, wherein receiving the instruction in the precise syntax from the NLP system is responsive to sending the API call to the NLP system, include the instruction in the precise syntax in the workspace document such that the spreadsheet application executed by one or more

computer processors can evaluate the instruction in the precise syntax, and after including the instruction in the precise syntax in the workspace document, evaluate the instruction in the precise syntax.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of an example system **100** in which a user can utilize natural language (NL) to create a software program in a precise syntax and/or utilize a computational application that is configured to execute instructions, functions, commands, formulas, etc., in a precise syntax, according to an embodiment.

FIG. **2** is a flow diagram of an example method for assisting with the development of instruction(s) in a precise syntax in a system such as the system of FIG. **1**, in an embodiment.

FIG. **3** is a flow diagram of another example method for assisting with the development of instruction(s) in a precise syntax in a system such as the system of FIG. **1**, in an embodiment.

FIG. **4** is a flow diagram of another example method for assisting with the development of instruction(s) in a precise syntax in a system such as the system of FIG. **1**, in an embodiment.

FIGS. **5**A-**5**E illustrate an example of display information utilized when entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment.

FIG. **6** is a flow diagram of an example method for including in a workspace NL input and instruction(s) in a precise context that correspond to the input, according to an embodiment.

FIG. **7** is a flow diagram of another example method for assisting with the development of instruction(s) in a precise syntax in a system such as the system of FIG. **1**, in an embodiment.

FIGS. **8**A and **8**B illustrate another example of display information utilized when entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment.

FIGS. **9**A and **9**B illustrate another example of display information utilized when entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment.

FIGS. **10**A-**10**E illustrate another example of display information utilized when entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment.

FIG. **11** illustrates another example of display information utilized when entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment.

FIGS. **12**A and **12**B illustrate another example of display information utilized when entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment.

FIG. **13** is a block diagram of an example computational system with which at least some of the methods and techniques described herein may be implemented, in an embodiment.

DETAILED DESCRIPTION

FIG. **1** is a diagram of an example system **100** in which a user can utilize natural language (NL) to create a software program in a precise syntax and/or utilize a computational application that is configured to execute instructions, functions, commands, formulas, etc., in a precise syntax, according to an embodiment.

A user computer **104** is communicatively coupled to a communication network **108** such as the Internet, an intranet, an extranet, etc. A server system **112** is also communicatively coupled to the network **108**. The user computer **104** is configured to facilitate software development and/or to implement a computational application such as the MATHEMATICA® computational application from Wolfram Research, Inc., a spreadsheet application, etc. The user computer **104** is also configured to communicate with the server system **112** via the network **108**. In particular, the user computer **104** may be configured to transmit electronically to the server system **112**, via the network **108**, NL user input that is indicative of one or more of an instruction, a function, a command, etc., a set of instructions/functions/commands etc., a set of software instructions, etc., in a precise syntax. The server system **112** may be configured to analyze the NL user input from the user computer **104** and to determine an instruction, a function, a command, etc., a set of instructions/functions/commands etc., a set of software instructions, etc., in a precise syntax that corresponds to the NL user input. The server system **112** may be configured to transmit electronically to the user computer **104**, via the network **108**, the determined instruction, function, command, etc., set of instructions/functions/commands etc., set of software instructions, etc.

The user computer **104** may be a computing device such as a desktop computer, a gaming system, a tablet computer, a smart phone, etc. The user computer **104** may include one or more processors **116**, one more memory devices **120** (e.g., random access memory (RAM), read only memory (ROM), FLASH memory, a magnetic disk, an optical disk, etc.), one or more display devices **124** (e.g., integral display device and/or external display device), and one or more input devices, such as a keyboard, a keypad, a button, a mouse, a trackball, a touch screen, a multi-touch screen, a touch pad, etc. The user computer **104** may include a network interface **132** to communicatively couple the user computer **104** to the network **108**. At least some of the one or more processors **116**, the one or more memory devices **120**, the one or more display devices **124**, the one or more input devices **128**, and the network interface **132** may be communicatively coupled together via one or more busses (not shown), cords (not shown), etc.

The one or more memory devices may store a software development application **136** and/or a computational application **140**. The software development application **136**, when executed by the one or more processors **120**, may enable a user to develop a software program. For example, the software development application **136** may include a source code editor (not shown). The software development application **136** may be configured to enable, when the software development application **136** is executed by the one or more processors **120**, a user to enter a NL user input that is indicative of one or more of a software instruction, function, etc., a set of software instructions/functions etc., and to forward the NL user input to the server system **112**. Additionally, the software development application **136** may be configured to incorporate into the software program being developed by the user, when the software development

application **136** is executed by the one or more processors **120**, a software instruction, function, etc., a set of software instructions/functions etc., received from the server system **112**.

The computational application **140**, when executed by the one or more processors **120**, may perform numerical, graphical, and/or symbolic calculations corresponding to functions, commands, instructions, formulas, etc., in a precise syntax, entered by the user in an electronic worksheet, spreadsheet, workbook, etc. For example, the computational application **140** may execute or interpret the entered functions, commands, instructions, formulas, etc., and perform corresponding numerical and/or symbolic calculations to generate corresponding results, which the computational application **140** may display in the electronic worksheet, spreadsheet, workbook, etc. The computational application **140** may be configured to enable, when the computational application **140** is executed by the one or more processors **120**, a user to enter a NL user input that is indicative of one or more of a function, command, instruction, formula, etc., a set of functions, commands, instructions, formulas, etc., and to forward the NL user input to the server system **112**. Additionally, the computational application **140** may be configured to incorporate into the electronic worksheet, spreadsheet, workbook, etc., being developed by the user, when the computational application **140** is executed by the one or more processors **120**, a function, command, instruction, formula, etc., a set of functions/commands/instructions/formulas, etc., received from the server system **112**.

For brevity, the terms "instruction in a precise syntax" and "instructions in a precise syntax" will be used to refer software code, instruction(s), function(s), etc., in a precise syntax, and/or function(s), command(s), instruction(s), formula(s), etc., in a precise syntax that are capable of being executed and/or interpreted by a computational application.

The server system **112** may comprise one or more computing devices such as a desktop computer, a server, a mainframe, etc. The server system **112** may include one or more processors **144**, one more memory devices **148** (e.g., RAM, ROM, FLASH memory, a magnetic disk, an optical disk, a database system, etc.), and a network interface **152** to communicatively couple the server system **112** to the network **108**. At least some of the one or more processors **144**, the one or more memory devices **148**, and the network interface **152** may be communicatively coupled together via one or more of 1) one or more busses, 2) one or more networks (e.g., a local area network (LAN), a wide area network (WAN), etc.) 3) point-to-point communication links, 4) cords, etc. (not shown).

The one or more memory devices **148** may store a software development assistance system application **160**. The software development assistance system application **160**, when executed by the one or more processors **144**, may assist a user in using the software development application **136** and/or the computational application **140**. For example, the software development assistance system application **160**, when executed by the one or more processors **144**, may receive from the user computer **104** NL user input that is indicative of instruction(s) in a precise syntax. Additionally, the software development assistance system application **160**, when executed by the one or more processors **144**, may determine instruction(s) in a precise syntax that correspond to the NL user input. Additionally, the software development assistance system application **160**, when executed by the one or more processors **144**, may cause the determined instruction(s) in the precise syntax to be transmitted to the user computer **104** via the network **108**.

FIG. **2** is a flow diagram of an example method **200** for assisting with the development of instruction(s) in a precise syntax in a system such as the system **100** of FIG. **1** or in another suitable system, in an embodiment. For example, the software development assistance system application **160**, when executed by the one or more processors **144**, may implement the method **200**. The method **200** of FIG. **2** will be discussed with reference to the system **100** of FIG. **1** for ease of explanation, but the method **200** may be implemented in a suitable system other than the system **100** of FIG. **1**.

At block **210**, NL input corresponding to instruction(s) in a precise syntax is electronically received. For example, as discussed above, the user may enter the NL input via the software development application **136** or the computational application **140** executed by the user computer **104**. The user computer **104** may then electronically transmit the NL input via the network **108** to the server system **112**. The server system **112** thus may electronically receive the NL input. In an embodiment, the NL input may be received as an application programming interface (API) call to the software development assistance system application **160**.

At block **214**, an NL processing (NLP) system may process the NL input in an attempt to determine a result (i.e., instruction(s) in a precise syntax) that corresponds to the NL input. For instance, the software development assistance system application **160** may include an NLP system that, when executed by the one or more processors **144**, may utilize suitable NLP techniques to attempt to determine instruction(s) in a precise syntax that correspond to the NL input.

At block **218**, it may be determined whether a result (an i.e., instruction(s) in a precise syntax) were generated at block **214**. If is determined that a result was not generated at block **214**, the flow may proceed to block **222**. At block **222**, suitable error handling may be performed. For example, a message may be electronically to the user computer **104** to indicate that the server system **112** was unable to generate a result in response to the NL input.

If at block **218** it is determined that a result was generated at block **214**, the flow may proceed to block **226**. At block **226**, the result may be formatted for inclusion in a workspace being utilized by the user for software development or development of instructions, commands, functions, formulas, etc., for processing by the computational application **140**. For example, the result may be formatted for inclusion in a workspace of the software development application **136** or of the computational application **140**. For example, the result may be formatted as text, XML, formatted according to a format recognized by the software development application **136**, formatted according to a format recognized by the computational application **140**, etc.

At block **230**, the result may be electronically transmitted to the user computer. For example, as discussed above, the server system **112** may electronically transmit the result via the network **108** to the user computer **104**.

FIG. **3** is a flow diagram of an example method **250** for assisting with the development of instruction(s) in a precise syntax in a system such as the system **100** of FIG. **1** or in another suitable system, in an embodiment. For example, the software development assistance system application **160**, when executed by the one or more processors **144**, may implement the method **250**. The method **250** of FIG. **3** will be discussed with reference to the system **100** of FIG. **1** for ease of explanation, but the method **250** may be implemented in a suitable system other than the system **100** of FIG. **1**.

At block **260**, NL input corresponding to instruction(s) in a precise syntax is electronically received. For example, as discussed above, the user may enter the NL input via the software development application **136** or the computational application **140** executed by the user computer **104**. The user computer **104** may then electronically transmit the NL input via the network **108** to the server system **112**. The server system **112** thus may electronically receive the NL input. In an embodiment, the NL input may be received as an API call to the software development assistance system application **160**.

At block **264**, an NLP system may process the NL input in an attempt to determine one or more results (i.e., instruction(s) in a precise syntax) that corresponds to the NL input. For instance, the software development assistance system application **160** may include an NLP system that, when executed by the one or more processors **144**, may utilize suitable NLP techniques to attempt to determine instruction(s) in a precise syntax that correspond to the NL input. In many instances, the NLP system may generate multiple results that correspond to the NL input. When the NLP system generates multiple results that correspond to the NL input, the NLP system may select a subset of the results in at least some situations. For example, when the number of results exceeds a threshold, the NLP system may select a subset of the results such that the subset does not exceed the threshold. The NLP system may be configured to rank results when multiple results are generated. Additionally or alternatively, the NLP system may be configured to indicate one of the results as a primary result when multiple results are generated.

At block **268**, the NLP system may process the NL input to generate other information based on the NL input and/or instruction(s) in the precise syntax generated at block **264**. The other information generated at block **268** may or may not include instruction(s) in a precise syntax. For instance, if the NLP system is able to determine instruction(s) in a precise syntax at block **264**, the NLP system may generate information associated with the instruction(s) in the precise syntax generated at block **264**. For example, if instruction(s) in the precise syntax generated at block **264** include instruction(s) that correspond to a function y with respect to a variable x, the NLP system may generate a plot of y versus x. As another example, the NLP system may determine a derivative of y with respect to x. As another example, the NLP system may determine an integral of y over x. As another example, if instruction(s) in the precise syntax generated at block **264** correspond to sorting a set of values from lowest to highest, the NLP system may generate instruction(s) in the precise syntax that correspond to sorting the set of values from highest to lowest.

Additionally, the NLP system may generate information that corresponds to only a portion of the NL input. For instance, the NLP system may attempt to determine instruction(s) in a precise syntax that corresponds to only a portion of the NL input. As another example, the NLP system may generate information that is not instruction(s) in a precise syntax. For instance, if the portion of the NL input is the text "sin x," the NLP system may generate information related to the trigonometric function sin(x), such as a plot of the trigonometric function sin(x), sin(x) expressed as the mathematical constant e, the derivative of sin(x), the integral of sin(x), etc.

Thus, in some embodiments, generating the other information based on the NL input may include determining a mathematical expression that corresponds to at least a portion of the NL input and determining information mathematically, statistically, or scientifically related to the mathematical expression.

At block **272**, results generated at block **264** and/or block **268** may be formatted for inclusion or display in a workspace being utilized by the user for software development or development of instructions, commands, functions, formulas, etc., for processing by the computational application **140**. For example, results that are instruction(s) in a precise syntax may be formatted for inclusion in a workspace of the software development application **136** or of the computational application **140**. For example, the result may be formatted as text, XML, formatted according to a format recognized by the software development application, formatted according to a format recognized by the computational application, etc. Results that are not instruction in a precise syntax may be formatted for display in a workspace of the software development application **136** or of the computational application **140**. For example, the result may be formatted as text, XML, HTML, image data (e.g., JPEG, TIFF, etc), formatted according to a format recognized by the software development application **136**, formatted according to a format recognized by the computational application **140**, etc.

If the results have been ranked by the NLP system, block **272** may include utilizing the rank information and/or rank information may be included in the formatted results. Similarly, if one of the results is marked by the NLP system as a primary result, block **272** may include utilizing such information and/or such information may be included in the formatted results. For example, rank information and/or primary result information may be utilized to order the results in the formatted results and/or to select a first result in a list of results in the formatted results.

At block **276**, the result may be electronically transmitted to the user computer. For example, as discussed above, the server system **112** may electronically transmit the result via the network **108** to the user computer **104**.

In an embodiment, the software development assistance system application **160**, when executed by the one or more processors **144**, may implement both the method **200** and the method **250**. For example, the method **200** may be invoked by a first API call and the method **250** may be invoked by a second API call. In other embodiments, the software development assistance system application **160**, when executed by the one or more processors **144**, may implement one of the method **200** and the method **250**.

FIG. **4** is a flow diagram of an example method **300** for assisting with the development of instruction(s) in a precise syntax in a system such as the system **100** of FIG. **1** or in another suitable system, in an embodiment. For example, the software development application **136** or the computational application **140**, when executed by the one or more processors **116**, may implement the method **300**. The method **300** of FIG. **4** will be discussed with reference to the system **100** of FIG. **1** for ease of explanation, but the method **300** may be implemented in a suitable system other than the system **100** of FIG. **1**.

At block **310**, NL input corresponding to instruction(s) in a precise syntax is electronically received. For example, as discussed above, the user may enter the NL input via a keyboard, a touch screen, a voice recognition system, etc., of the user computer **104**. The NL input may then be electronically received by the software development application **136** or the computational application **140**.

At block **314**, an API call that includes the NL input is generated and electronically transmitted to the server system

112. For example, the user computer **104** may generate the API call that includes the NL input, and then electronically transmit the API call via the network **108** to the server system **112**. For instance, the software development application **136** or the computational application **140**, when executed by the one or more processors **116**, may generate the API call and cause the API call to be transmitted.

At block **318**, it may be determined if a result was received from the server system **112** in response to the API call transmitted at block **314**. If is determined that a result was not received, the flow may proceed to block **322**. For example, if a message from the server system **112** indicates that the server system **112** was not able to generate instruction(s) in a precise syntax in response to the API call transmitted at block **314**, the flow may proceed to block **322**. At block **222**, suitable error handling may be performed. For example, a message may be presented to the user by the user computer **104** to indicate that the server system **112** was unable to generate instruction(s) in a precise syntax in response to the NL input. The message may be displayed on the display device **124**, generated as an audio signal using an audio output device of the user computer **104**.

If at block **318** it is determined that a result (i.e., instruction(s) in the precise syntax) was received, the flow may proceed to block **326**. At block **326**, the instruction(s) in the precise syntax may be included in a workspace being utilized by the user for software development or development of instructions, commands, functions, formulas, etc., for processing by the computational application **140**. In one embodiment, the instruction(s) in the precise syntax may be included in a workspace automatically without any further user input. In another embodiment, the user may be prompted (e.g., via the display device **124** and/or an audio output device of the user computer **104**) whether to include the instruction(s) in the precise syntax in the workspace. For example, a window may display to the user the instruction(s) in the precise syntax and the user may be prompted to choose (e.g., using a suitable user input mechanism) whether to include the instruction(s) in the workspace.

If the method **300** is implemented by the computational application **140**, at block **330**, the instruction(s) in the precise syntax are evaluated by the computational application **140**. In one embodiment, the instruction(s) may be evaluated automatically after block **326** without any further user input. In another embodiment, a further user input (e.g., a key press, touch screen button press, etc.) is required to cause the instruction(s) to be evaluated.

FIGS. **5**A-**5**E illustrate an example of entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment. The example of FIGS. **5**A-**5**E may correspond to method **300** of FIG. **4**, and will be discussed with respect to FIG. **4** for ease of explanation. The example of FIGS. **5**A-**5**E may correspond, however, to another suitable method. Moreover, the method **300** may utilize suitable workspace displays other than the example of FIGS. **5**A-**5**E. The computational application **140** (FIG. **1**) may cause the display information illustrated in FIGS. **5**A-**5**E to be displayed on the display device **124**, in an embodiment. The example of FIGS. **5**A-**5**E is in the context of the MATHEMATICA® computational application. Similar workspace display information may be generated with other computational applications.

In FIG. **5**A, a prompt **354** may indicate a location at which the user can enter an input into the workspace. The user may enter text after the prompt **354**, and then press SHIFT-ENTER (i.e., press ENTER key while holding down the SHIFT key) to cause the computational application to process the user input, in an embodiment. Generally, the computational application may expect user input to be in a precise syntax. But when the user input is preceded by a special character or key press combination (e.g., CTRL-"=" or another suitable character or key press combination), the computational application treats the text **362** that follows the special character or key press combination as NL input (e.g., as in block **310** of FIG. **4**). In the example of FIG. **5**A, the user has pressed the "=" key while holding down the CTRL key (i.e., CTRL-"="), which results in the computational application displaying the symbol **358**. After entering the text **362**, and when the user presses SHIFT-ENTER, the computational application may generate an API call that includes the NL input **362** (e.g., as in block **314** of FIG. **4**).

In response to the API call, the computational application may receive a result from the server system **112** that includes an instruction in a precise syntax that corresponds to the NL input **362**. The computational application may then cause the text **362** to be replaced in the workspace by a display portion **370** (FIG. **5**B). The display portion **370** may include the NL input **362**. The display portion **370** may also include the instruction **374** in the precise syntax (e.g., as in block **326** of FIG. **4**). The display portion **370** may also include a symbol **378** or other indicator to indicate that the portion **370** corresponds to interpretation of NL input. Additionally, in response to receiving the result, the computational application may evaluate the instruction **374** to generate an output, which is also displayed in the workspace (not shown).

As seen in FIG. **5**B, the workspace displays both the NL input **362** and the corresponding instruction **374** (i.e., an "Integrate" function provided by MATHEMATICA® computational application). This may provide viewers of the workspace a natural language explanation of the instruction **374** in the precise syntax.

The display portion **370** may include a user interface mechanism **382** and a user interface mechanism **386**. The user interface mechanism **382**, when selected by the user, may cause the NL input to be hidden on the workspace. For instance, FIG. **5**C illustrates the display portion **370** after the user has selected the user interface mechanism **382**. As seen in FIG. **5**C, the NL input **362** is now hidden. The display portion **370** may include a user interface mechanism **390** that, when selected, re-displays the NL input **362** and reverts the display portion **370** to the form illustrated in FIG. **5**B.

As seen in FIG. **5**C, the workspace displays the instruction **374** in the precise syntax but not the NL input **362** utilized to determine the instruction **374**. This may be useful, for example, when the user does not want NL inputs displayed on the workspace, but wants an option to view the NL input later by selecting the user interface mechanism **390**.

Referring now to FIG. **5**B, when the user interface mechanism **386** is selected by the user, the instruction **374** is hidden on the workspace. For instance, FIG. **5**D illustrates the display portion **370** after the user has selected the user interface mechanism **386**. As seen in FIG. **5**D, the instruction **374** is now hidden. The display portion **370** may include a user interface mechanism **394** that, when selected, re-displays the instruction **374** and reverts the display portion **370** to the form illustrated in FIG. **5**B.

As seen in FIG. **5**D, the workspace displays the NL input **362** utilized to determine the instruction **374** but not the instruction **374** itself. This may be useful, for example, when the user does not want instructions in a precise syntax

displayed on the workspace, but wants an option to view the instruction **374** later by selecting the user interface mechanism **394**.

Referring now to FIG. **5**B, the user may also select the instruction **374** itself, e.g., by moving a cursor over the instruction **374** and selecting the instruction **374**, touching a touch screen at a point over the instruction **374**, etc. Then, only the instruction **374** will be displayed on the workspace. For instance, FIG. **5**E illustrates the workspace after the user has selected the instruction **374**. As seen in FIG. **5**E, the NL input is now removed from the workspace.

As seen in FIG. **5**E, the workspace displays the instruction **374** in the precise syntax but not the NL input **362** utilized to determine the instruction **374**. This may be useful, for example, when the user does not want NL inputs displayed on the workspace, and does not want an option to view the NL input on the workspace at a later time.

FIG. **6** is a flow diagram of an example method **400** for including in a workspace NL input and instruction(s) in a precise context that correspond to the input, according to an embodiment. The workspace may be of a software development application or a computational application implemented by one or more processors, in an embodiment. The software development application **136** or the computational application **140**, when executed by the one or more processors **116**, may implement the method **400**. The method **400** of FIG. **6** will be discussed with reference to FIGS. **5**A-**5**E for ease of explanation, but the method **400** may be implemented with suitable display information other than display information such as depicted in FIGS. **5**A-**5**E. The method **400** may be implemented upon receiving instruction(s) in a precise syntax that correspond to NL input.

At block **410**, an indication of the NL input and an indication of the instruction(s) in the precise syntax may be displayed in a workspace of the software development application **136** or the computational application **140**. For example, the display portion **370** of FIG. **5**B may be displayed.

At block **414**, a first user interface mechanism to hide the indication of the NL input may be provided. For example, the user interface mechanism **382** of FIG. **5**B may be displayed in the workspace.

At block **418**, a second user interface mechanism to hide the instruction(s) in the precise syntax may be provided. For example, the user interface mechanism **386** of FIG. **5**B may be displayed in the workspace.

At block **422**, a third user interface mechanism to select the instruction(s) in the precise syntax may be provided. In an embodiment, the indication of the instruction(s) in the precise syntax may be associated with or correspond to the third interface mechanism. For instance, an area of the display screen that overlaps with the indication of the instruction(s) in the precise syntax may correspond to the third user interface mechanism. When this area is selected by the user, the third user interface mechanism may be activated. For example, as discussed above with reference to FIG. **5**B, a user can select the instruction(s) **374** by pressing a touch screen at a point over the instruction(s) **374**, by moving a cursor over the instruction(s) **374** and activating a selection button, etc.

At block **426**, it may be determined whether the first user interface mechanism was activated. For example, it may be determined whether the user selected the user interface mechanism **382** of FIG. **5**B by a touch screen press, cursor selection, etc. If it is determined that the user activated the first user interface mechanism, the flow may proceed to block **430**.

At block **430**, the indication of the NL input may be hidden on the workspace. For example, as discussed with respect to FIG. **5**C, the NL input **362** is hidden on the workspace. At block **434**, a fourth user interface mechanism to re-show the indication of the NL input may be provided. For example, as shown in FIG. **5**C, the user interface mechanism **390** is displayed in the workspace.

At block **438**, it may be determined whether the fourth user interface mechanism was activated. For example, it may be determined whether the user selected the user interface mechanism **390** of FIG. **5**C by a touch screen press, cursor selection, etc. If it is determined that the user activated the fourth user interface mechanism, the flow may proceed to block **442**.

At block **442**, the indication of the NL input may be re-shown in the workspace. For example, as discussed with respect to FIGS. **5**B and **5**C, the NL input **362** is re-shown on the workspace as in FIG. **5**B when the user selects the user interface mechanism **390** of FIG. **5**C.

On the other hand, if it is determined at block **438** that the user did not activate the fourth user interface mechanism, the flow may proceed to block **446**. At block **446**, it may be determined if the user selected the instruction(s) **374**. For example, it may be determined whether the user selected the instruction(s) **374** by a touch screen press, cursor selection, etc. If it is determined that the user activated the third user interface mechanism, the flow may proceed to block **450**.

At block **450**, the NL input may be removed from the workspace. Additionally, the first user interface mechanism, the second user interface mechanism, and the third user interface mechanism may be removed from the workspace. For example, as discussed with respect to FIGS. **5**B and **5**E, the display of the workspace may appear as in FIG. **5**E when the user selects the instruction(s) **374**.

On the other hand, if it is determined at block **446** that the user did not activate the third user interface mechanism, the flow may return to block **438**.

Referring again to block **426**, if it is determined that the user did not activate the first user interface mechanism, the flow may proceed to block **454**. At block **454**, it may be determined whether the second user interface mechanism was activated. For example, it may be determined whether the user selected the user interface mechanism **386** of FIG. **5**B by a touch screen press, cursor selection, etc. If it is determined that the user activated the second user interface mechanism, the flow may proceed to block **458**.

At block **458**, the indication of the instruction(s) in the precise syntax may be hidden on the workspace. For example, as discussed with respect to FIG. **5**D, the instruction(s) **374** is hidden on the workspace. At block **462**, a fifth user interface mechanism to re-show the instruction(s) in the precise syntax may be provided. For example, as shown in FIG. **5**D, the user interface mechanism **394** is displayed in the workspace.

At block **466**, it may be determined whether the fifth user interface mechanism was activated. For example, it may be determined whether the user selected the user interface mechanism **394** of FIG. **5**D by a touch screen press, cursor selection, etc. If it is determined that the user activated the fifth user interface mechanism, the flow may proceed to block **470**.

At block **470**, the indication of the instruction(s) in the precise syntax may be re-shown in the workspace. For example, as discussed with respect to FIGS. **5**B and **5**D, the instruction(s) **374** is re-shown on the workspace as in FIG. **5**B when the user selects the user interface mechanism **394** of FIG. **5**D.

On the other hand, if it is determined at block **466** that the user did not activate the fifth user interface mechanism, the flow may return to block **466** to continue checking whether the user activated the fifth user interface mechanism.

Referring again to block **454**, if it is determined that the user did not activate the second user interface mechanism, the flow may proceed to block **474**. At block **474**, it may be determined whether the third user interface mechanism was activated. For example, it may be determined whether the user selected the instruction(s) **374** of FIG. **5**B or **5**C by a touch screen press, cursor selection, etc. If it is determined that the user activated the third user interface mechanism, the flow may proceed to block **450**. As discussed above, at block **450**, the NL input may be removed from the workspace. Additionally, the first user interface mechanism, the second user interface mechanism, and the third user interface mechanism may be removed from the workspace. For example, as discussed with respect to FIGS. **5**B and **5**E, the display of the workspace may appear as in FIG. **5**E when the user selects the instruction(s) **374**.

FIG. **7** is a flow diagram of an example method **500** for assisting with the development of instruction(s) in a precise syntax in a system such as the system **100** of FIG. **1** or in another suitable system, in an embodiment. For example, the software development application **136** or the computational application **140**, when executed by the one or more processors **116**, may implement the method **500**. The method **500** of FIG. **7** will be discussed with reference to the system **100** of FIG. **1** for ease of explanation, but the method **500** may be implemented in a suitable system other than the system **100** of FIG. **1**.

At block **510**, NL input corresponding to instruction(s) in a precise syntax is electronically received. For example, as discussed above, the user may enter the NL input via a keyboard, a touch screen, a voice recognition system, etc., of the user computer **104**. The NL input may then be electronically received by the software development application **136** or the computational application **140**.

At block **514**, a first API call that includes the NL input is generated and electronically transmitted to the server system **112**. For example, the user computer **104** may generate the first API call that includes the NL input, and then electronically transmit the first API call via the network **108** to the server system **112**. For instance, the software development application **136** or the computational application **140**, when executed by the one or more processors **116**, may generate the first API call and cause the first API call to be transmitted. In one embodiment, the first API call causes the server system **112** to implement the method **200** of FIG. **2**. In other embodiments, the first API call causes the server system **112** to implement a suitable method other than the method **200** of FIG. **2**.

At block **518**, it may be determined if a result was received from the server system **112** in response to the first API call transmitted at block **514**. If it is determined that a result (i.e., instruction(s) in the precise syntax) was received, the flow may proceed to block **522**. At block **522**, the instruction(s) in the precise syntax may be included in a workspace being utilized by the user for software development or development of instructions, commands, functions, formulas, etc., for processing by the computational application **140**. In one embodiment, the instruction(s) in the precise syntax may be included in a workspace automatically without any further user input. In another embodiment, the user may be prompted (e.g., via the display device **124** and/or an audio output device of the user computer **104**) whether to include the instruction(s) in the precise syntax in the workspace. For example, a window may display to the user the instruction(s) in the precise syntax and the user may be prompted to choose (e.g., using a suitable user input mechanism) whether to include the instruction(s) in the workspace.

If the method **500** is implemented by the computational application **140**, at block **526**, the instruction(s) in the precise syntax are evaluated by the computational application **140**. In one embodiment, the instruction(s) may be evaluated automatically after block **526** without any further user input. In another embodiment, a further user input (e.g., a key press, touch screen button press, etc.) is required to cause the instruction(s) to be evaluated.

Referring again to block **518**, if it is determined that a result was not received, the flow may proceed to block **530**. For example, if a message from the server system **112** indicates that the server system **112** was not able to generate instruction(s) in a precise syntax in response to the first API call transmitted at block **514**, the flow may proceed to block **530**.

At block **530**, a second API call that includes the NL input is generated and electronically transmitted to the server system **112**. For example, the user computer **104** may generate the second API call that includes the NL input, and then electronically transmit the second API call via the network **108** to the server system **112**. For instance, the software development application **136** or the computational application **140**, when executed by the one or more processors **116**, may generate the second API call and cause the second API call to be transmitted. In one embodiment, the second API call causes the server system **112** to implement the method **250** of FIG. **3**. In other embodiments, the second API call causes the server system **112** to implement a suitable method other than the method **250** of FIG. **3**.

At block **534**, if multiple results are received in response to the second API call, one of the received results is selected. Various suitable techniques for selecting one of the received results may be utilized. Additionally, selecting one of the received results may be based on various factors. For example, if the received results include both instruction(s) in the precise syntax and other information that are not instructions in the precise syntax, one of the results including instruction(s) in the precise syntax may be selected. Additionally, a ranking applied to the server system **112** may be utilized to select one of the results. For example, a highest ranked result may be selected. Similarly, if the server system **112** marks one of the results as a primary result, the primary result may be selected. As another example, if the results are provided in an order, the first result in the order may be selected. Other suitable techniques and/or factors may also be utilized.

At block **538**, the selected result may be included in the workspace. In one embodiment, the result may be included in a workspace automatically without any further user input. In another embodiment, the user may be prompted (e.g., via the display device **124** and/or an audio output device of the user computer **104**) whether to include the result in the workspace. For example, a window may display to the user the result and the user may be prompted to choose (e.g., using a suitable user input mechanism) whether to include the result in the workspace.

At block **542**, it may be determined if the result included in the workspace at block **538** includes instruction(s) in the precise syntax. If it is determined that the result includes instruction(s) in the precise syntax, the flow may proceed to block **526** at which the instruction(s) in the precise syntax are operated upon. On the other hand, if it is determined at

block **542** that the result included in the workspace at block **538** does not include instruction(s) in the precise syntax, the flow may end.

FIGS. **8**A and **8**B illustrate an example of entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment. The example of FIGS. **8**A and **8**B may correspond to the method **500** of FIG. **7**, and will be discussed with respect to FIG. **7** for ease of explanation. The example of FIGS. **8**A and **8**B may correspond, however, to another suitable method. Moreover, the method **700** may utilize suitable workspace displays other than the example of FIGS. **8**A and **8**B. The computational application **140** (FIG. **1**) may cause the display information illustrated in FIGS. **8**A and **8**B to be displayed on the display device **124**, in an embodiment. The example of FIGS. **8**A-**8**B is in the context of the MATHEMATICA® computational application. Similar workspace display information may be generated with other computational applications.

In FIG. **8**A, a prompt **554** may indicate a location at which the user can enter an input into the workspace. The user may enter text after the prompt **554**, and then press SHIFT-ENTER (i.e., press ENTER key while holding down the SHIFT key) to cause the computational application to process the user input, in an embodiment. Generally, the computational application may expect user input to be in a precise syntax. But when the user input is preceded by a special character or key press combination (e.g., "=" or another suitable character or key press combination), the computational application treats the text **558** that follows the special character or key press combination as NL input (e.g., as in block **510** of FIG. **7**). In the example of FIG. **8**A, the user has pressed the "=" key and then entered further text **558**, which results in the computational application displaying the symbol **562**. After entering the text **558**, and when the user presses SHIFT-ENTER, the computational application may generate a first API call that includes the NL input **558** (e.g., as in block **514** of FIG. **7**).

In response to the first API call, the computational application may receive a result from the server system **112** that includes an instruction in a precise syntax that corresponds to the NL input **558**. The computational application may then cause the text **558** to be replaced in the workspace by a display portion **570** (FIG. **8**B). The display portion **570** may include the NL input **558**. The display portion **570** may also include the instruction **574** in the precise syntax (e.g., as in block **522** of FIG. **7**). In FIG. **8**B, the instruction in the precise syntax **574** is a "Mean" function provided by MATHEMATICA® computational application. Additionally, in response to receiving the result, the computational application may evaluate the instruction **574** to generate an output, which is also displayed in the workspace. In particular, an output **582** is displayed after a prompt **586**, in an embodiment.

As seen in FIG. **8**B, the workspace displays both the NL input **558** and the corresponding instruction **574**. This may provide viewers of the workspace a natural language explanation of the instruction **574** in the precise syntax.

The display portion **570** may include a user interface mechanism **590**. The user interface mechanism **590**, when selected by the user, may permit a user to obtain information regarding the NL input **558** and/or the instruction **574**. For example, the user interface mechanism **590**, when selected by the user, may permit a user to obtain the instruction **574** in different formats, for example. Different formats may include, for example, a text format.

If the server system **112** returns multiple results, the user interface mechanism **590** may be utilized to choose a different one of the results. For example, FIGS. **9**A and **9**B illustrate an example of entering NL input into a workspace of a computational application, and then including corresponding instructions in a precise format in the workspace, according to an embodiment. The example of FIGS. **9**A and **9**B may correspond to the method **500** of FIG. **7**, and will be discussed with respect to FIG. **7** for ease of explanation. The example of FIGS. **9**A and **9**B may correspond, however, to another suitable method. Moreover, the method **700** may utilize suitable workspace displays other than the example of FIGS. **9**A and **9**B. The computational application **140** (FIG. **1**) may cause the display information illustrated in FIGS. **9**A and **9**B to be displayed on the display device **124**, in an embodiment. The example of FIGS. **9**A-**9**B is in the context of the MATHEMATICA® computational application. Similar workspace display information may be generated with other computational applications.

In FIG. **9**A, the user has entered the NL input **610**. After entering the NL input **610**, and when the user presses SHIFT-ENTER, the computational application may generate a first API call that includes the NL input **610** (e.g., as in block **514** of FIG. **7**), in an embodiment.

In response to the first API call, the computational application may receive a message from the server system **112** that the server system **112** was unable to determine a single result (i.e., instruction(s) in the precise syntax) corresponding to the NL input **610**. For example, the server system **112** may determine that there are multiple results.

In response to the message from the server system, the computational application may generate a second API call that includes the NL input **610** (e.g., as in block **530** of FIG. **7**). In response to the second API call, the computational application may receive a result from the server system **112** that includes multiple results, wherein each of at least some of the results comprises instruction(s) in a precise syntax that corresponds to the NL input **610**. The computational application may then select one of the results (as in block **534** of FIG. **7**).

The computational application may then cause the text **610** to be replaced in the workspace by a display portion **620** (FIG. **9**B). The display portion **620** may include the NL input **610**. The display portion **620** may also include the instruction **624** in the precise syntax (e.g., as in block **538** of FIG. **7**).

The display portion **620** may also include an indication **628** that other results were returned. Further, the display portion **620** may include a user interface mechanism **632**. The user interface mechanism **632**, when selected by the user, may permit a user to view and/or select other ones of the results returned in response to the second API call.

Additionally, in response to selecting one of the results and if the selected result is an instruction(s) in the precise syntax, the computational application may evaluate the instruction **624** to generate an output, which is also displayed in the workspace. In particular, an output **640** is displayed.

In some embodiments, NL input can be utilized for arguments, parameters, etc. within an instruction in a precise syntax (hereinafter referred to as "parameters" or "parameters of an instruction in a precise syntax" for brevity). For example, FIGS. **10**A-**10**E illustrate an example of entering an instruction in a precise syntax into a workspace of a computational application, except that a parameter of the instruction is expressed using NL input (i.e., the parameter is not in the precise syntax), according to an embodiment. In

response, the server system **112** may determine instruction(s) entirely in a precise syntax, according to an embodiment. The example of FIGS. **10**A-**10**E may correspond to the method **300** of FIG. **4**, and will be discussed with respect to FIG. **4** for ease of explanation. The example of FIGS. **10**A-**10**E may correspond, however, to another suitable method. Moreover, the method **300** may utilize suitable workspace displays other than the example of FIGS. **10**A-**10**E. The computational application **140** (FIG. **1**) may cause the display information illustrated in FIGS. **10**A-**10**E to be displayed on the display device **124**, in an embodiment. The example of FIGS. **10**A-**10**E is in the context of the MATHEMATICA® computational application. Similar workspace display information may be generated with other computational applications.

In the example of FIG. **10**A, the user entered text **650** corresponding to an instruction in a precise syntax (i.e., the "Series" function provided by MATHEMATICA® computational application). In this example, the Series function is function that includes two arguments including a first argument which is an expression for which a power series approximation is desired. A second argument is a set of three sub-arguments $\{x, x_0, n\}$. The Series function determines a power series approximation of the expression (first argument) about the point $x=x_0$ to order at most $(x-x_0)^n$.

In the example of FIG. **10**A, in place of the first argument of the Series function, the user has pressed the "=" key while holding down the CTRL key (i.e., CTRL-"="), which results in the computational application displaying the symbol **660**. Next, the user has entered text **664** corresponding to a NL description of the first argument of the Series function. Next, the user enters a comma **668**. The comma **668** may indicate an end of text corresponding to the first argument. Next, the user enters text **672** corresponding to the second argument of the Series function. The second argument has been entered in the precise syntax. Upon finishing entering text corresponding to the Series function, and the user presses SHIFT-ENTER and the computational application processes the user input.

The computational application may determine that the user input of FIG. **10**A corresponds to the Series function in the precise syntax, except that the first parameter is expressed using NL. In response, the computational application may generate an API call that includes the NL input **664** (e.g., as in block **314** of FIG. **4**).

In response to the API call, the computational application may receive a result from the server system **112** that includes the first argument in a precise syntax that corresponds to the NL input **664**. The computational application may then cause the text **664** to be replaced in the workspace by a display portion **680** (FIG. **10**B). The display portion **680** may include the NL input **664**. The display portion **680** may also include the first argument in the precise syntax **684** (e.g., as in block **326** of FIG. **4**). The display portion **680** may also include the symbol **660** or other indicator to indicate that the portion **680** corresponds to interpretation of NL input. Additionally, in response to receiving the response to the API call, the computational application may evaluate the Series function with the argument **684** to generate an output **686**, which is also displayed in the workspace.

As seen in FIG. **10**B, the workspace displays both the NL input **664** and the corresponding precise syntax argument **684** that corresponds to the NL input **664**. This may provide viewers of the workspace a natural language explanation of the argument **684** in the precise syntax.

The display portion **680** may include a user interface mechanism **690** and a user interface mechanism **692**. The user interface mechanism **690**, when selected by the user, may cause the argument **684** in the precise syntax to be hidden on the workspace. For instance, FIG. **10**C illustrates the display portion **680** after the user has selected the user interface mechanism **690**. As seen in FIG. **10**C, the argument **684** in the precise syntax is now hidden. The display portion **680** may include a user interface mechanism **694** that, when selected, re-displays the argument **684** in the precise syntax and reverts the display portion **680** to the form illustrated in FIG. **10**B.

As seen in FIG. **10**C, the workspace displays the first argument of the Series function as NL input, but not the argument **684** in the precise syntax. This may be useful, for example, when the user does not want the precise syntax displayed on the workspace, but wants an option to view the precise syntax later by selecting the user interface mechanism **694**.

Referring now to FIG. **10**B, when the user interface mechanism **692** is selected by the user, the NL input **664** is hidden on the workspace. For instance, FIG. **10**D illustrates the display portion **680** after the user has selected the user interface mechanism **692**. As seen in FIG. **10**D, the argument **684** in the precise syntax is now hidden. The display portion **680** may include a user interface mechanism **696** that, when selected, re-displays the argument **684** in the precise syntax and reverts the display portion **680** to the form illustrated in FIG. **10**B.

As seen in FIG. **10**D, the workspace displays the argument **684** in the precise syntax but not the NL input **664**. This may be useful, for example, when the user does not want NL input displayed on the workspace, but wants an option to view the NL input later by selecting the user interface mechanism **696**.

Referring now to FIG. **10**B, the user may also select the argument **684** in the precise syntax itself, e.g., by moving a cursor over the argument **684** in the precise syntax and selecting the argument **684** in the precise syntax, touching a touch screen at a point over the argument **684** in the precise syntax, etc. Then, only the argument **684** in the precise syntax will be displayed on the workspace. For instance, FIG. **10**E illustrates the workspace after the user has selected the argument **684** in the precise syntax. As seen in FIG. **10**E, the NL input **664** is now removed from the workspace.

As seen in FIG. **10**E, the workspace displays the argument **684** in the precise syntax but not the NL input **664** utilized to determine the argument **684** in the precise syntax. This may be useful, for example, when the user does not want NL input displayed on the workspace, and does not want an option to view the NL input on the workspace at a later time.

A method similar to the method **400** of FIG. **6** may utilize display techniques such as described in FIGS. **10**A-**10**E may be employed to for including in a workspace NL input and instruction(s) in a precise context that correspond to the input, according to an embodiment. The workspace may be of a software development application or a computational application implemented by one or more processors, in an embodiment. The software development application **136** or the computational application **140**, when executed by the one or more processors **116**, may implement such a method. Such a method may include determining that the user has entered text corresponding to an instruction in a precise syntax, except that one or more arguments of the instruction are entered using NL. In response to each argument determined to be entered as NL, the computational application may issue a respective API call to the server system and, in

response, receive precise syntax corresponding to the argument. Then, the computational application may evaluate the instruction.

An argument entered using NL may include an instruction, and/or a known value. For example, an argument in NL could correspond to an instruction such as "derivative of sin x". Additionally, an argument in NL could correspond to a known value (i.e., known to the server system **112**) such as "speed of light" or "population of France."

In some embodiments, the computational application and/or the software development application, when sending NL input to the server system **112** (e.g., via an API call), may include information regarding instruction(s) previously entered in the workspace, and/or results already included on the workspace, that may provide context for interpreting the NL input. For example, FIGS. **11**A-**11**B illustrate an example in which information regarding instructions previously entered into a workspace, and/or results already included on the workspace, of a computational application are utilized for interpreting NL input.

The example of FIG. **11** may be utilized in connection with the method **500** of FIG. **7**, and will be discussed with respect to FIG. **7** for ease of explanation. The example of FIG. **11** may correspond, however, to another suitable method such as the method **300** of FIG. **4**. Moreover, the methods **300** and **700** may utilize suitable workspace displays other than the example of FIG. **11**. The computational application **140** (FIG. **1**) may cause the display information illustrated in FIG. **11** to be displayed on the display device **124**, in an embodiment. The example of FIG. **11** is in the context of the MATHEMATICA® computational application. Similar workspace display information may be generated with other computational applications.

In the example of FIG. **11**, the user entered NL text **710** corresponding to an instruction in a precise syntax (i.e., the "Show" function and the "Plot" function provided by MATHEMATICA® computational application). The computational application then sent a first API call that includes the NL input **710** (e.g., as in block **514** of FIG. **7**) to the server system **112**. In response to the first API call, the server system **112** may return an instruction **720** in a precise syntax. In particular, the server system **112** returns a "Show" function that includes as an argument a "Plot" function. The instruction **720** is then included in the workspace (e.g., as in block **522** of FIG. **7**). Next, the computational application may evaluate the instruction **720** to generate an output **730** included on the workspace. The output **730** includes a plot of a sinusoid.

Optionally, if the instruction **720** is not returned in response to the first API call, the computational application may send a second API call that includes the NL input **710** (e.g., as in block **530** of FIG. **7**) to the server system **112**. In response to the second API call, the server system **112** may return a plurality of results, and the computational application may select the instruction **720** in a precise syntax from the results (e.g., as in block **534** of FIG. **7**). The instruction **720** is then included in the workspace (e.g., as in block **538** of FIG. **7**), and evaluated (as in block **526** of FIG. **7**).

Next, the user entered NL text **740** corresponding to an instruction in a precise syntax (i.e., the "Show" function provided by MATHEMATICA® computational application). In particular, the NL text **740** corresponds to an instruction to add red dashed grid lines to the plot **730**. The computational application then sent a first API call that includes the NL input **740** (e.g., as in block **514** of FIG. **7**) to the server system **112**. The first API call also includes information that indicates that a "Show" function and/or "Plot" function was previously entered in the workspace and/or that the last result generated by the computational application was a plot. In response to the first API call, the server system **112** may return an instruction **750** in a precise syntax. In particular, the server system **112** returns a "Show" function that includes as an argument the "%" symbol, which is precise syntax indicating the last result generated by the computational application (i.e., the plot **730**). The instruction **750** is then included in the workspace (e.g., as in block **522** of FIG. **7**). Next, the computational application may evaluate the instruction **750** to generate an output **760** included on the workspace. The output **760** corresponds to the plot **730** but with red dashed grid lines.

Optionally, if the instruction **740** is not returned in response to the first API call, the computational application may send a second API call that includes the NL input **740** (e.g., as in block **530** of FIG. **7**) to the server system **112**. The second API call also includes information that indicates that a "Show" function and/or "Plot" function was previously entered in the workspace and/or that the last result generated by the computational application was a plot. In response to the second API call, the server system **112** may return a plurality of results, and the computational application may select the instruction **750** in a precise syntax from the results (e.g., as in block **534** of FIG. **7**). The instruction **750** is then included in the workspace (e.g., as in block **538** of FIG. **7**), and evaluated (as in block **526** of FIG. **7**).

Thus, the server system **112** (e.g., the software development assistance system **160**, when executed by the one or more processors **144**) may be configured to utilize information from the software development application **136** and/or the computational application **140** regarding instructions already entered into the workspace and/or results already included on the workspace, in some embodiments.

With regard to instructions related to plotting functions and/or data, the server system **112** (e.g., the software development assistance system **160**, when executed by the one or more processors **144**) may be configured to analyze NL input to determine a dimension of the plot (e.g., 2-dimensional or 3-dimensional) to be generated and to generate the instruction(s) in a precise context accordingly. In one embodiment, the server system **112** (e.g., the software development assistance system **160**, when executed by the one or more processors **144**) may be configured to analyze NL input to determine how many variables are to be plotted.

For instance FIG. **12**A illustrates an example in which a user has entered NL input **810** that corresponds to generating a plot of several functions that are all a function of a variable x. The server system **112** analyzed the NL input **810** and determined that the NL input **810** corresponds to a "Plot" function provided by the MATHEMATICA® computational application, i.e., a function to create a 2-dimensional plot. The server system **112** generated the instruction **816** in the precise syntax, and the computational application evaluated the instruction **816** to generate a 2-dimensional plot **820**.

On the other hand, FIG. **12**B illustrates an example in which a user has entered NL input **830** that corresponds to generating a plot of a function of two variables x and y. The server system **112** analyzed the NL input **830** and determined that the NL input **830** corresponds to a "Plot3D" function provided by MATHEMATICA® computational application, i.e., a function to create a 3-dimensional plot of a function of two variables. The server system **112** generated the instruction **836** in the precise syntax, and the computational application evaluated the instruction **836** to generate a 3-dimensional plot **840**.

The example of FIGS. **12**A-**12**B is in the context of the MATHEMATICA® computational application. Similar workspace display information may be generated with other computational applications.

As seen in the examples of FIGS. **11**, **12**A and **12**B, a computational application may permit generation of plots such as 2-dimensional and 3-dimensional plots. Using techniques such as described above, however, a user may be able to style such plots by entering less text, at least in some situations, and without necessarily knowing precise syntax normally required to perform such styling. For example, as illustrated in FIG. **11**, a user may specify the line color of a curve (e.g., "dark brown") and shade areas "under" the curve with a desired color (e.g., "light orange") merely by entering the NL input "plot sin x in dark brown with light orange filling." The server system **112** may determine precise syntax **720** necessary to perform such styling, e.g., "Show [PlotSin[x], . . . PlotStyle->Darker[Brown], { . . . FillingStyle->Lighter[Orange]}]]". Similarly, a user can add red dashed grid lines to the plot merely by entering the NL input "add red dashed grid lines." The server system **112** may determine precise syntax **760** necessary to perform such styling, e.g., "Show[%, . . . GridLinesStyle->Directive[Red, Dashed]]".

Similarly, other styling can be applied using a NL input. For example, if a user desires a particular line thickness (e.g., 3 point thickness) of a plot, the user may enter the NL input "set line thickness 3". The server system **112** may determine precise syntax necessary to perform such styling, e.g., "MapAt[{AbsoluteThickness[3], #1} &, %, 1]". As a further example, if a user desires to change the background to a particular color (e.g., light yellow mixed with light gray) of a plot, the user may enter the NL input "change background to light yellow+light gray". The server system **112** may determine precise syntax necessary to perform such styling, e.g., "Show[%, Background->RGBColor [0.8333333333333333, 0.8333333333333333, 0.5]". As yet another example, if a user desires to add a frame with tick marks to a plot, the user may enter the NL input "add frame". The server system **112** may determine precise syntax necessary to perform such styling, e.g., "Show[%, Frame->True]".

In some embodiments, techniques such as described above can be utilized to perform image processing functions. For example, if image data has been included in the workspace, and if a user desires to apply an "oil painting" effect, the user may enter the NL input "oil painting". The server system **112** may determine precise syntax necessary to perform such image processing on the image date in the workspace, e.g., "ImageEffect[%, "OilPainting"]". Similarly, if image data has been included in the workspace, and if a user desires to apply a "solarization" effect, the user may enter the NL input "solarization effect". The server system **112** may determine precise syntax necessary to perform such image processing on the image date in the workspace, e.g., "ImageEffect[%, "Solarization"]". Similarly, if image data has been included in the workspace, and if a user desires to apply an "embossing" effect, the user may enter the NL input "emboss image". The server system **112** may determine precise syntax necessary to perform such image processing on the image date in the workspace, e.g., "ImageEffect[%, "Embossing"]".

Although a key press (e.g., "=") or a combination of key presses (e.g., CTRL-"=") were described above as techniques for indicating NL input, other suitable techniques may be utilized. For example, a pull-down menu, a pop-up menu, a button press, a touch screen action (e.g., a swipe, a circular motion, a swipe pattern, press-and-hold, etc.) may be utilized to indicate text is NL input. As a specific example, a user may select a menu item corresponding to a request to enter NL input. In response to the selection, a window may open to prompt a user to enter text into a text box, for example. Then, the user may press ENTER, SHIFT-ENTER, press a button, etc., to indicate that the user is finished entering the NL input.

Although techniques above were described in the context of a computational application and/or the MATHEMATICA® computational application, similar techniques can be utilized with the software development application **136** (FIG. **1**). For example, a method similar to the method **300** of FIG. **4** may be implemented by the software development application **136**. For instance, instruction(s) in a precise syntax may be included in a workspace corresponding to a source code file. The block **330** may be omitted or modified so that the instruction(s) in precise syntax is/are processed by the software development application **136**. In one embodiment, the software development application **136** may be configured to include the NL input utilized to determine the instruction(s) in precise syntax in the workspace as comments.

As another example, a method similar to the method **500** of FIG. **7** may be implemented by the software development application **136**. For instance, instruction(s) in a precise syntax may be included in a workspace corresponding to a source code file. The block **526** may be omitted or modified so that the instruction(s) in precise syntax is/are processed by the software development application **136**. In one embodiment, the software development application **136** may be configured to include the NL input utilized to determine the instruction(s) in precise syntax in the workspace as comments. The user may be prompted visually, audibly, etc., to include the NL input as comments, and the user may press a button, etc., to cause the NL input to be included as comments.

Referring again to FIG. **1**, the server system **112** may utilize systems and techniques in U.S. patent application Ser. No. 11/852,044, filed on Sep. 7, 2007, and/or in U.S. patent application Ser. No. 12/780,685, filed on May 14, 2010, which are hereby incorporated by reference herein in their entireties. For instance, in an embodiment, the server system **112** may implement a system the same as or similar to the systems described. For example, the server system **112** may implement one or more scanners including a scanner configured to instructions in a precise syntax (e.g., instructions that adhere to a precise syntax of a software programming language or instructions that adhere to a precise syntax utilized by a computational application (e.g., the instructions correspond to built-in functions of the computational application)). In one embodiment, the scanner is configured to generate one or more sets of instruction(s) in precise syntax corresponding to an NL input.

In an embodiment, the server system **112** may be configured to determine one or more sets of instruction(s) in the precise syntax that correspond to the NL input. For example, there might be multiple interpretations of the NL input, and the multiple sets of instruction(s) in the precise syntax may correspond to the multiple interpretations. If multiple sets of instruction(s) in the precise syntax are determined, the multiple sets may be evaluated the multiple sets to eliminate sets and/or rank sets. For example, sets may be evaluated for code size, memory use efficiency, code readability metrics, simplicity, etc. Also, sets that result in unwanted operations such as a "divide-by-zero", an infinite loop, etc., may be eliminated. If the server system **112** is configured to imple-

ment a method such as the method **200** of FIG. **2**, and if multiple sets of instruction(s) in the precise syntax are determined, at most one set may be selected for transmission to the user computer. If the server system **112** is configured to implement a method such as the method **250** of FIG. **3**, and if multiple sets of instruction(s) in the precise syntax are determined, multiple sets may be transmitted to the user computer. Additionally, if the server system **112** is configured to implement a method such as the method **250** of FIG. **3**, results generated from other types of scanners such as described in U.S. patent application Ser. No. 11/852,044, filed on Sep. 7, 2007, and/or in U.S. patent application Ser. No. 12/780,685, filed on May 14, 2010, may be transmitted to the user computer.

FIG. **13** is a block diagram of an example computational system **900** with which at least some of the methods and techniques described above may be implemented, in an embodiment. For example, the computational system **900** may implement a computational application such as described above. The system **900** comprises a kernel **904** in data communication with a front end **908**. In general, the kernel **904** may comprise software components that, when executed by one or more processors of a computer system, perform computations such as numeric computations, symbolic computations, graphic computations, etc. The front end **908** may comprise software components that, when executed by one or more processors of a computer system, handle interaction with a user. For example, the front end **908** may be configured to permit the user to enter expressions to be evaluated by the kernel **904**, to permit a user to initiate evaluations of expressions, to display results of evaluations to the user, etc.

The kernel **904** and the front end **908** may be implemented on a same computing system or on different computing systems that are communicatively coupled to one another. For example, referring to FIG. **1**, the kernel **904** and the front end **908** may be implemented by the user computer **104** (e.g., the computational application **140** may comprise the kernel **904** and the front end **908**). As another example, the front end **908** may be implemented by the user computer **104**, whereas the kernel **904** may be implemented by the server system **112** or another suitable server system. Thus, the kernel **904** and the front end **908** may communicate via a communication link that comprises one or more of procedure calls, messages, a proprietary application programming interface (API) (e.g., the API provided by MATHLINK® software available from Wolfram Research, Inc.), etc. Additionally, if the kernel **904** and the front end **908** are implemented on different computing systems, the kernel **904** and the front end **908** may communicate via the network **108** and/or another suitable network or communication link.

The front end **908** may include an interactive document referred to as a notebook similar to those often used with MATHEMATICA® computational system. A notebook may include input to be sent to the kernel **904** and output received from the kernel **904**, as well as text, graphics, palettes, etc. A notebook may include menus and graphical tools for creating and reading notebook documents and for sending information to and receiving information from the kernel **904**. The notebook may be utilized as a workspace in which NL input and/or instruction(s) in a precise syntax are included, such as described above. The precise syntax may be the syntax specified by the MATHEMATICA® computational system, in an embodiment.

The method **300** may be implemented by a system such as the system **900**. For example, blocks **310**, **314**, **318**, **322** and **326** may be implemented by the front end **908**, and block **330** may be implemented by the kernel **904**, in an embodiment. In other embodiments, the blocks of the method **300** may be implemented by the system **900** in other suitable ways. Similarly, the method **500** may be implemented by a system such as the system **900**. For example, blocks **510**, **514**, **518**, **522**, **530**, **534**, **538**, and **542** may be implemented by the front end **908**, and blocks **522** and **526** may be implemented by the kernel **904**, in an embodiment. In other embodiments, the blocks of the method **500** may be implemented by the system **900** in other suitable ways. Similarly, the method **400** may be implemented by the front end **908**.

Throughout this specification, plural instances may implement components, operations, or structures described as a single instance. Although individual operations of one or more methods are illustrated and described as separate operations, one or more of the individual operations may be performed concurrently, and nothing requires that the operations be performed in the order illustrated. Structures and functionality presented as separate components in example configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements fall within the scope of the subject matter herein.

Additionally, certain embodiments are described herein as including logic or a number of components, modules, or mechanisms. Modules may constitute either software modules (e.g., code embodied on a machine-readable medium or in a transmission signal) or hardware modules. A hardware module is tangible unit capable of performing certain operations and may be configured or arranged in a certain manner. In example embodiments, one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware modules of a computer system (e.g., a processor or a group of processors) may be configured by software (e.g., an application or application portion) as a hardware module that operates to perform certain operations as described herein.

In various embodiments, a hardware module may be implemented mechanically or electronically. For example, a hardware module may comprise dedicated circuitry or logic that is permanently configured (e.g., as a special-purpose processor, such as a programmable logic device (PLD) or an application-specific integrated circuit (ASIC)) to perform certain operations. A hardware module may also comprise programmable logic or circuitry (e.g., as encompassed within a general-purpose processor or other programmable processor) that is temporarily configured by software to perform certain operations. It will be appreciated that the decision to implement a hardware module mechanically, in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by cost and time considerations.

Accordingly, the term "hardware module" should be understood to encompass a tangible entity, be that an entity that is physically constructed, permanently configured (e.g., hardwired), or temporarily configured (e.g., programmed) to operate in a certain manner or to perform certain operations described herein. As used herein, "hardware-implemented module" refers to a hardware module. Considering embodiments in which hardware modules are temporarily configured (e.g., programmed), each of the hardware modules need not be configured or instantiated at any one instance in time. For example, where the hardware modules comprise a general-purpose processor configured using software, the general-purpose processor may be configured as respective

different hardware modules at different times. Software may accordingly configure a processor, for example, to constitute a particular hardware module at one instance of time and to constitute a different hardware module at a different instance of time.

Hardware modules can provide information to, and receive information from, other hardware modules. Accordingly, the described hardware modules may be regarded as being communicatively coupled. Where multiple of such hardware modules exist contemporaneously, communications may be achieved through signal transmission (e.g., over appropriate circuits and buses) that connect the hardware modules. In embodiments in which multiple hardware modules are configured or instantiated at different times, communications between such hardware modules may be achieved, for example, through the storage and retrieval of information in memory structures to which the multiple hardware modules have access. For example, one hardware module may perform an operation and store the output of that operation in a memory device to which it is communicatively coupled. A further hardware module may then, at a later time, access the memory device to retrieve and process the stored output. Hardware modules may also initiate communications with input or output devices, and can operate on a resource (e.g., a collection of information).

The various operations of example methods described herein may be performed, at least partially, by one or more processors that are temporarily configured (e.g., by software) or permanently configured to perform the relevant operations. Whether temporarily or permanently configured, such processors may constitute processor-implemented modules that operate to perform one or more operations or functions. The modules referred to herein may, in some example embodiments, comprise processor-implemented modules.

Similarly, the methods or routines described herein may be at least partially processor-implemented. For example, at least some of the operations of a method may be performed by one or processors or processor-implemented hardware modules. The performance of certain of the operations may be distributed among the one or more processors, not only residing within a single machine, but deployed across a number of machines. In some example embodiments, the processor or processors may be located in a single location (e.g., within a home environment, an office environment or as a server farm), while in other embodiments the processors may be distributed across a number of locations.

The one or more processors may also operate to support performance of the relevant operations in a "cloud computing" environment or as a "software as a service" (SaaS). For example, at least some of the operations may be performed by a group of computers (as examples of machines including processors), these operations being accessible via a network (e.g., the Internet) and via one or more appropriate interfaces (e.g., application program interfaces (APIs).)

The performance of certain of the operations may be distributed among the one or more processors, not only residing within a single machine, but deployed across a number of machines. In some example embodiments, the one or more processors or processor-implemented modules may be located in a single geographic location (e.g., within a home environment, an office environment, or a server farm). In other example embodiments, the one or more processors or processor-implemented modules may be distributed across a number of geographic locations.

Some portions of this specification are presented in terms of algorithms or symbolic representations of operations on data stored as bits or binary digital signals within a machine memory (e.g., a computer memory). These algorithms or symbolic representations are examples of techniques used by those of ordinary skill in the data processing arts to convey the substance of their work to others skilled in the art. As used herein, an "algorithm" is a self-consistent sequence of operations or similar processing leading to a desired result. In this context, algorithms and operations involve physical manipulation of physical quantities. Typically, but not necessarily, such quantities may take the form of electrical, magnetic, or optical signals capable of being stored, accessed, transferred, combined, compared, or otherwise manipulated by a machine. It is convenient at times, principally for reasons of common usage, to refer to such signals using words such as "data," "content," "bits," "values," "elements," "symbols," "characters," "terms," "numbers," "numerals," or the like. These words, however, are merely convenient labels and are to be associated with appropriate physical quantities.

Unless specifically stated otherwise, discussions herein using words such as "processing," "computing," "calculating," "determining," "presenting," "displaying," or the like may refer to actions or processes of a machine (e.g., a computer) that manipulates or transforms data represented as physical (e.g., electronic, magnetic, or optical) quantities within one or more memories (e.g., volatile memory, non-volatile memory, or a combination thereof), registers, or other machine components that receive, store, transmit, or display information.

As used herein any reference to "one embodiment" or "an embodiment" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase "in one embodiment" or the phrase "in an embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

Some embodiments may be described using the expression "coupled" and "connected" along with their derivatives. For example, some embodiments may be described using the term "coupled" to indicate that two or more elements are in direct physical or electrical contact. The term "coupled," however, may also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other. The embodiments are not limited in this context.

As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

In addition, use of the "a" or "an" are employed to describe elements and components of the embodiments herein. This is done merely for convenience and to give a general sense of the description. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

Still further, the figures depict preferred embodiments of a computational application system for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein

Upon reading this disclosure, those of skill in the art will appreciate still additional alternative structural and functional designs for a system and a process for identifying terminal road segments through the disclosed principles herein. Thus, while particular embodiments and applications have been illustrated and described, it is to be understood that the disclosed embodiments are not limited to the precise construction and components disclosed herein. Various modifications, changes and variations, which will be apparent to those skilled in the art, may be made in the arrangement, operation and details of the method and apparatus disclosed herein without departing from the spirit and scope defined in the appended claims.

What is claimed is:

1. A method, comprising:

receiving, via a user interface device, user input for inclusion in a workspace document, wherein the workspace document is displayed in a graphical user interface of a software development application that, when executed by one or more computer processors, is configured to evaluate instructions in a precise syntax;

after receiving the user input, displaying, on a display device, the user input in the workspace document;

determining, at the one or more computer processors, whether at least a portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax;

when it is determined that at least the portion of the user input is in the precise syntax,

evaluating, at the one or more computer processors, at least the portion of the user input according to the precise syntax;

when it is determined that at least the portion of the user input is in the imprecise syntax,

generating, at the one or more computer processors, an application programming interface (API) call that includes i) the at least the portion of the user input in the imprecise syntax, and ii) information indicating a result of a previous evaluation, by the software development application, of a user input previously entered into the workspace document,

sending, by the one or more computer processors, the API call to a natural language processing (NLP) system implemented by one or more computer processors,

processing, at the NLP system, the API call to determine the instruction in the precise syntax that corresponds to the user input in the imprecise syntax, wherein the instruction in the precise syntax is for generating a modification of the result of the previous evaluation,

formatting, at the NLP system, the instruction in the precise syntax according to a format recognized by the software development application,

receiving, at the one or more computer processors, the instruction in the precise syntax from the NLP system, wherein receiving the instruction in the precise syntax from the NLP system is responsive to sending the API call to the NLP system,

including, by one or more computer processors, the instruction in the precise syntax in the workspace document such that the software development application executed by one or more computer processors can evaluate the instruction in the precise syntax, and

after including the instruction in the precise syntax in the workspace document, evaluating, at one or more computing devices, the instruction in the precise syntax.

2. The method of claim **1**, wherein determining whether the at least a portion of the user input i) is in the precise syntax, or ii) is in the imprecise syntax, includes:

analyzing the user input to determine if the user input includes a user indication, in the precise syntax, that indicates whether the at least the portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax.

3. The method of claim **1**, wherein:

the user input is first user input;

the instruction in the precise syntax is a first instruction in the precise syntax;

the method further comprises:

receiving, via the user interface device, second user input for inclusion in the workspace document, the second user input including a second instruction in the precise syntax,

after receiving the second user input, displaying, on the display device, the second user input in the workspace document, and

after including the second instruction in the precise syntax in the workspace document, evaluating, at one or more computing devices, the second instruction in the precise syntax;

the first user input indicates an argument of the second instruction;

the first instruction is included in the workspace document such that the first instruction is included in the workspace document as an argument of the second instruction; and

evaluating the second instruction in the precise syntax comprises evaluating the first instruction as an argument of the second instruction.

4. The method of claim **1**, further comprising:

displaying, on the display device, a display portion at a location in the workspace document at which at least the portion of the user input in the imprecise syntax was displayed prior to determining the instruction in the precise syntax;

wherein the display portion simultaneously includes at least the portion of the user input in the imprecise syntax and the instruction in the precise syntax.

5. The method of claim **1**, wherein:

sending the API call to the NLP system comprises sending the API call to the NLP system via a communication network; and

receiving the instruction in the precise syntax from the NLP system comprises receiving the instruction in the precise syntax from the NLP system via the communication network.

6. One or more tangible, non-transitory computer readable storage media, storing machine readable instructions that, when executed by one or more computer processors, cause the one or more processors to:

receive, via a user interface device, user input for inclusion in a workspace document, wherein the workspace document is displayed in a graphical user interface of a software development application that, when executed by one or more computer processors, is configured to evaluate instructions in a precise syntax;

after receiving the user input, display, on a display device, the user input in the workspace document;

determine whether at least a portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax;

when it is determined that at least the portion of the user input is in the precise syntax, evaluate at least the portion of the user input according to the precise syntax;

when it is determined that at least the portion of the user input is in the imprecise syntax,

generate an application programming interface (API) call that includes i) the at least the portion of the user input in the imprecise syntax, and ii) information indicating a result of a previous evaluation, by the software development application, of a user input previously entered into the workspace document,

send the API call to a natural language processing (NLP) system implemented by the one or more computer processors,

process, at the NLP system, the API call to determine the instruction in the precise syntax that corresponds to the user input in the imprecise syntax, wherein the instruction in the precise syntax is for generating a modification of the result of the previous evaluation,

format, at the NLP system, the instruction in the precise syntax according to a format recognized by the spreadsheet application,

receive the instruction in the precise syntax from the NLP system, wherein receiving the instruction in the precise syntax from the NLP system is responsive to sending the API call to the NLP system,

include the instruction in the precise syntax in the workspace document such that the spreadsheet application executed by one or more computer processors can evaluate the instruction in the precise syntax, and

after including the instruction in the precise syntax in the workspace document, evaluate the instruction in the precise syntax.

7. The one or more tangible, non-transitory computer readable storage media of claim **6**, further storing machine readable instructions that, when executed by the one or more computer processors, cause the one or more processors to:

determine whether the at least a portion of the user input i) is in the precise syntax, or ii) is in the imprecise syntax, at least by analyzing the user input to determine if the user input includes a user indication, in the precise syntax, that indicates whether the at least the portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax.

8. The one or more tangible, non-transitory computer readable storage media of claim **6**, wherein:

the user input is first user input;

the instruction in the precise syntax is a first instruction in the precise syntax;

the one or more tangible, non-transitory computer readable storage media further store machine readable instructions that, when executed by the one or more computer processors, cause the one or more processors to:

receive, via the user interface device, second user input for inclusion in the workspace document, the second user input including a second instruction in the precise syntax,

after receiving the second user input, display, on the display device, the second user input in the workspace document, and

after including the second instruction in the precise syntax in the workspace document, evaluate the second instruction in the precise syntax;

the first user input indicates an argument of the second instruction;

the first instruction is included in the workspace document such that the first instruction is included in the workspace document as an argument of the second instruction; and

evaluating the second instruction in the precise syntax comprises evaluating the first instruction as an argument of the second instruction.

9. The one or more tangible, non-transitory computer readable storage media of claim **6**, further storing machine readable instructions that, when executed by the one or more computer processors, cause the one or more processors to:

display a display portion at a location in the workspace document at which at least the portion of the user input in the imprecise syntax was displayed prior to determining the instruction in the precise syntax;

wherein the display portion simultaneously includes at least the portion of the user input in the imprecise syntax and the instruction in the precise syntax.

10. The one or more tangible, non-transitory computer readable storage media of claim **6**, wherein:

the one or more computer processors comprises at least a first computer processor and at least a second computer processor; and

the one or more tangible, non-transitory computer readable storage media further stores machine readable instructions that, when executed by the one or more computer processors, cause the one or more processors to:

send the API call from a computer to a server system via a communication network, wherein the computer comprises the at least the first computer processor and the server system comprising the at least the second computer processor, and

receive the instruction in the precise syntax at the computer from the server system.

11. A system, comprising:

one or more computer processors;

one or more tangible, non-transitory computer readable storage media storing machine readable instructions that, when executed by one or more computer processors, cause the one or more processors to:

receive, via a user interface device, user input for inclusion in a workspace document, wherein the workspace document is displayed in a graphical user interface of a software development application that, when executed by one or more computer processors, is configured to evaluate instructions in a precise syntax;

after receiving the user input, display, on a display device, the user input in the workspace document;

determine whether at least a portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax;

when it is determined that at least the portion of the user input is in the precise syntax, evaluate at least the portion of the user input according to the precise syntax;

when it is determined that at least the portion of the user input is in the imprecise syntax,

generate an application programming interface (API) call that includes i) the at least the portion of the user input in the imprecise syntax, and ii) information indicating a result of a previous evaluation, by the

software development application, of a user input previously entered into the workspace document,

send the API call to a natural language processing (NLP) system implemented by the one or more computer processors,

process, at the NLP system, the API call to determine the instruction in the precise syntax that corresponds to the user input in the imprecise syntax, wherein the instruction in the precise syntax is for generating a modification of the result of the previous evaluation,

format, at the NLP system, the instruction in the precise syntax according to a format recognized by the spreadsheet application,

receive the instruction in the precise syntax from the NLP system, wherein receiving the instruction in the precise syntax from the NLP system is responsive to sending the API call to the NLP system,

include the instruction in the precise syntax in the workspace document such that the spreadsheet application executed by one or more computer processors can evaluate the instruction in the precise syntax, and

after including the instruction in the precise syntax in the workspace document, evaluate the instruction in the precise syntax.

12. The system of claim **11**, wherein the one or more tangible, non-transitory computer readable storage media further store machine readable instructions that, when executed by the one or more computer processors, cause the one or more processors to:

determine whether the at least a portion of the user input i) is in the precise syntax, or ii) is in the imprecise syntax, at least by analyzing the user input to determine if the user input includes a user indication, in the precise syntax, that indicates whether the at least the portion of the user input i) is in the precise syntax, or ii) is in an imprecise syntax.

13. The system of claim **11**, wherein:

the user input is first user input;

the instruction in the precise syntax is a first instruction in the precise syntax;

the one or more tangible, non-transitory computer readable storage media further store machine readable instructions that, when executed by the one or more computer processors, cause the one or more processors to:

receive, via the user interface device, second user input for inclusion in the workspace document, the second user input including a second instruction in the precise syntax,

after receiving the second user input, display, on the display device, the second user input in the workspace document, and

after including the second instruction in the precise syntax in the workspace document, evaluate the second instruction in the precise syntax;

the first user input indicates an argument of the second instruction;

the first instruction is included in the workspace document such that the first instruction is included in the workspace document as an argument of the second instruction; and

evaluating the second instruction in the precise syntax comprises evaluating the first instruction as an argument of the second instruction.

14. The system of claim **11**, wherein the one or more tangible, non-transitory computer readable storage media further store machine readable instructions that, when executed by the one or more computer processors, cause the one or more processors to:

display a display portion at a location in the workspace document at which at least the portion of the user input in the imprecise syntax was displayed prior to determining the instruction in the precise syntax;

wherein the display portion simultaneously includes at least the portion of the user input in the imprecise syntax and the instruction in the precise syntax.

15. The system of claim **11**, wherein:

the one or more computer processors comprises at least a first computer processor and at least a second computer processor; and

the system comprises i) a computer that includes the at least the first computer processor, and ii) a server system that includes the at least the second computer processor;

the computer is communicatively coupled to the server system via a network;

the one or more tangible, non-transitory computer readable storage media comprises i) a first one or more tangible, non-transitory computer readable storage media, and ii) a second one or more tangible, non-transitory computer readable storage media;

the computer includes the first one or more tangible, non-transitory computer readable storage media;

the server system includes the second one or more tangible, non-transitory computer readable storage media;

the first one or more tangible, non-transitory computer readable storage media further store machine readable instructions that, when executed by the at least the first computer processor, cause the at least the first computer processor to:

send the API call to the server system via the communication network; and

the second one or more tangible, non-transitory computer readable storage media further store machine readable instructions that, when executed by the at least the second computer processor, cause the at least the second computer processor to:

send the instruction in the precise syntax to the one or more computer processors via the communication network in response to the API call.

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